(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

CORRECTED VERSION

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 August 2000 (10.08.2000)

PCT

(10) International Publication Number
WO 00/46938 A1

(51) International Patent Classification[7]: H04B 7/204, 7/212, 7/216, H04Q 7/20, 7/22, 7/24

(21) International Application Number: PCT/US00/02797

(22) International Filing Date: 4 February 2000 (04.02.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/245,292 5 February 1999 (05.02.1999) US

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(81) Designated States (*national*): AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

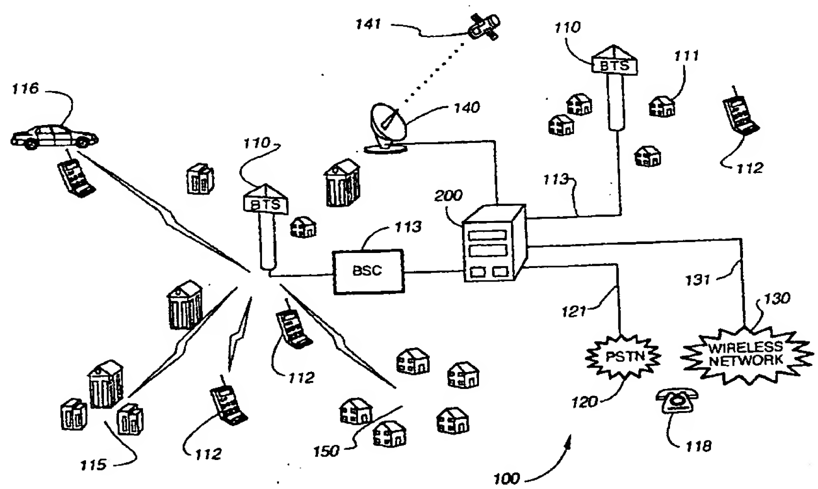
(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

(48) Date of publication of this corrected version:
28 March 2002

[Continued on next page]

(54) Title: MULTI-PROTOCOL WIRELESS COMMUNICATION APPARATUS AND METHOD



WO 00/46938 A1

(57) Abstract: A scalable, multi-protocol mobile switching center (200) in a wireless communications network provides communications control for digital and analog wireless communication devices (110, 112, 115, 116, 118, 140) including devices that operate according to GSM and IS-31 standards. The hardware and software architecture of the switching center is designed so that processing that is unique to a particular protocol is performed at the lowest possible level, and remaining processing can use generic procedures. The switching center incorporates a home location register and visitor location register that are used in conjunction with software applications to determine the protocol of mobile communications devices using the wireless communication network. The mobile switching center can be used to provide a large scale distributed wireless network or a small scale wireless network. The switching center can also be used as an adjunct to a private branch exchange to provide in-building wireless services and call control. Graphical user interfaces make the wireless communications network easy to maintain.

(15) Information about Correction:
see PCT Gazette No. 13/2002 of 28 March 2002, Section II

MULTI-PROTOCOL WIRELESS COMMUNICATION APPARATUS AND METHOD

Field Of The Invention

The invention is directed to a wireless communications apparatus and method. In particular, the invention is directed to a multi-protocol, scaleable wireless switching platform and method.

Background

Wireless communications in the United States were initially conducted solely through analog systems and protocols. The most prevalent analog protocol remains the Advanced Mobile Telephone System (AMPS) protocol. To handle wireless communications and to allow interconnection with traditional wired land-lines, switching systems and base stations were required. The analog switching systems are large and are designed to cover large markets and handle large volumes of calls.

In the 1990's digital systems and protocols began to be used for wireless communications. Examples of digital protocols are the Global System for Mobile Communication (GSM) code division multiple access (CDMA), and time division multiple access (TDMA). When wireless networks began to switch to digital protocols, they could not simply upgrade their analog base stations to digital. New equipment for the digital facilities was required. However, the networks continued to use large switching systems designed to cover their large spread markets. Examples of large switching systems are AT&T's 5ESS® system and the AXE system made by Ericsson. The 5ESS® switch is described in detail in the AT&T Technical Journal, Vol. 64, No. 6, part 2, July/August 1985, pages 1305-1564.

Large switching systems are designed to cover large markets and to handle many thousands of customers. The larger systems have the advantage of being able to provide a wide range of call options, such as call forwarding, caller identification and call waiting. The switching systems are expensive, however and, therefore, may not be appropriate for small markets and wireless providers. Additionally, large switching systems can be inefficient because of the added additional cost for increased back hauls of calls.

Typical switching systems employ proprietary architectures that use hardware components for switching, external interfaces, operating system, and control.

Summary Of The Invention

A multi-protocol mobile switching center (MSC) provides wireless communications for mobile devices operating on a local wireless network according to any standard protocol including those of the Global Systems for Mobile Communications (GSM) standards and IS-41 standards (including time division multiple access (TDMA), code division multiple access (CDMA), and Advanced Mobile Telephone System (AMPS)). The MSC may be incorporated onto a single platform having a home location register (HLR) and an authentication center (AC or AuC), as well as a visitor location register (VLR) and an equipment identity register (EIR).

The multi-protocol MSC is scalable so that it may be used for a small number of customers, such as in a rural setting to provide telephone access, or as part of an in-building communications network. The scalable, multi-protocol MSC may also be used to construct a large, distributed wireless network. Thus, the scalable, multi-protocol MSC provides the flexibility to be used with a wide range of customer bases, and within a variety of different typographies.

Because the MSC can process wired and wireless calls according to any protocol, a single switching center may serve customers who operate mobile and fixed communications devices, regardless of protocol. This true multi-protocol functionality makes this switching solution extremely efficient and cost effective, and eliminates the need for separate, protocol-specific components.

The multi-protocol MSC can be housed in a standard chassis. The multi-protocol MSC can use standard, off the shelf hardware for most data storage and processing functions. The multi-protocol MSC can be easily updated to take advantage of industry advances by simply replacing select components in the chassis.

The multi-protocol MSC provides full-featured telephone and data services, including wired and wireless analog and digital telephony, conference calling, prepaid

calling, emergency call routing and long-distance resale. The multi-protocol MSC also provides pocket switching applications such as asynchronous transfer mode (ATM).

The multi-protocol MSC incorporates advanced graphical user interfaces (GUIs) that display system data in a convenient, easy to access format. A system operator can quickly select data for display, and can easily modify selected data entries. The system operator can control operation of the multi-protocol MSC using the intuitively structured GUIs.

The multi-protocol MSC may incorporate a number of sophisticated features in addition to the HLR, VLR, EIR and the authentication center. These features include an operations and maintenance center, wire line and tandeming services, and hot (real-time) billing and prepaid services.

When used for distributed switching, the multi-protocol MSC may reduce build out and operational costs associated with large switching centers. This architecture also eliminates needless back hauling by switching local calls locally. Finally, the architecture allows for add on as a wireless customer base expands.

The multi-protocol MSC includes a first interface that receives digital and analog communication according to a first protocol and a second interface that receives digital communication according to a second protocol. The first and the second interfaces include inter system (system-to-system) message handlers and intra system (within system) message handlers.

The hardware and software architecture of the MSC is designed to use generic signaling as much as possible to provide call connection and other functions. Protocol-specific communications are handled at a device handler (lower) level, and higher level processing uses generic messaging. A table may be used to map messages of the different protocols to the generic messages used by the MSC. The hardware of the aircore system is based on off-the-shelf industry standard components for each of the four areas typically found as proprietary in current systems. The use of

off-the-shelf standardized switching components, interface boards, operating system and control processing provide a unique evolution path for the aircore system.

The HLR and VLR are structured so that data that does not depend on a specific protocol is stored in a common memory portion while protocol-specific data is stored in protocol specific portions of the HLR and VLR. This logical arrangement of the HLR and VLR provides for quick access to data by components of the MSC and allows for easier updating by a system operator.

An advanced intelligent message (AIM) handler interfaces with the VLR and the HLR to determine the current location and identification of mobile units homed on the HLR or roaming in the local wireless network. The AIM also determines the protocol applicable for the mobile unit. For calls received at the MSC from a local wireless network base station, the protocol determination may be made by reference to the protocol of the base station. For multi-protocol base stations, the determination includes decoding information provided in the service request or similar message sent by the base station. For other mobile units, the MSC may communicate with external wireless components such as other HLRs, VLRs, and MSCs.

The MSC includes an authentication and registration system that controls registration of mobile communications devices operating on the system controlled by the MSC. The authentication and registration system also provides encryption and ciphering of voice and data communications.

The MSC can also be used as an adjunct to a private branch exchange (PBX) to create an in-building wireless network. Used as such, the MSC and HLR can be used to route calls preferentially among mobile units and fixed telephones and other communications devices.

Brief Description Of The Drawings

The invention will be described in conjunction with the following figures, in which like numbers refer to like features, and wherein

Figures 1a - 1d show wireless communication environments according to the invention.

Figure 2 is a block diagram of an aircore switching platform.

Figure 3 shows a wireless loop architecture.

Figure 4 shows a fixed wireless loop architecture.

Figure 5 shows the aircore platform with local area mobility.

Figure 6 shows the aircore platform with system level mobility.

Figure 7 shows the aircore platform with full scale mobility.

Figure 8 shows a wireless network architecture.

Figure 9 is a block diagram of aircore functions.

Figures 10 is a block diagram of the aircore software architecture.

Figure 11 is a block diagram of the advanced intelligent message handler architecture.

Figure 12 is a block diagram of the A-interface message handler.

Figure 13 is a block diagram of the ISDN user part message handler.

Figure 14 is a block diagram of a intersystem message handler.

Figure 15 is a block diagram of a device handler for voice input-output devices.

Figure 16 is a block diagram of a device handler for digital interfaces.

Figure 17 is a block diagram of a device handler for ISDN interfaces.

Figure 18 is a block diagram of a device handler for signaling system 7 communication.

Figure 19 is a block diagram showing software interlayer communications.

Figure 20 is a logical representation of the home location register.

Figure 21 illustrates the HLR/VLR database structures.

Figure 22 is a block diagram illustrating the location management feature of the visitor location register.

Figure 23 is a state machine for mobile originated call processing.

Figure 24 is a state machine for PSTN originated call processing.

Figure 25 is a state machine for mobile terminated call processing.

Figure 26 is a diagram of a near end facility state machine.

Figures 27 is a diagram of a far end facility state machine.

Figure 28 is a diagram illustrating mobile unit hand off.

Figure 29a shows the software components used for call processing.

Figure 29b shows the object structure for the aircore call processing.

Figure 29c is a flow chart illustrating an authentication process.

Figures 30-34 are flow charts showing message signaling associated with interface maintenance.

Figures 35-40 are flow charts showing message signaling associated with trunk management.

Figures 41-47 are flow charts showing message signaling associated with mobility management.

Figures 48-66 are flow charts showing message signaling for call processing.

Figures 67-71 are flow charts showing message signaling associated with call processing with an external HLR.

Figures 72 is a flow chart showing message signaling associated with hand off pre-processing.

Figure 73 is a logical diagram of a prepaid rating system.

Figure 74 is a flow diagram illustrating emergency call processing.

Figure 75 is a block diagram illustrating first party call control.

Figure 76 is a block diagram illustrating third party call control.

Figures 77-79 are block diagrams of call delivery methods using third party call control.

Figure 80 is a block diagram of an in-building wireless communications network.

Figures 81-84 are block diagrams of an embodiment of the aircore platform hardware architecture.

Figures 85-86 are block diagrams of another embodiment of the aircore platform hardware architecture.

Figures 87-123 illustrate graphic user interface screens for use with the aircore platform.

Detailed Description Of The Invention

Mobile telecommunications (radio) systems that permit customer calling from mobile stations such as automobiles, or small light weight hand held personal communications units are becoming increasingly prevalent. These systems use the principles of cellular technology to allow the same frequencies of a common allocating radio bandwidth to be reused in separated local areas or cells of a broader region. Each cell is served by a base transceiver station comprising a group of local transceivers connected to a common antenna. Base station systems, each including a controller and one or more transceiver stations, are interconnected via a switching system, called a mobile switching center (MSC), which is also connected to the public switched telephone network (PSTN), and the Public Land Mobile Telephone Network (PLMN). These mobile telecommunications systems are now entering a second generation characterized by digital radio communications with a different set of standards, such as the European Global System for Mobile Communications (GSM) standard promulgated by the Special Mobile Group (SMG). The GSM standard is also being adapted for use in the United States. In addition, in the United States, CDMA, TDMA, DAMPS, and AMPS are used for digital cellular mobile communications.

The mobile telecommunications systems have many components that need to communicate signaling information for controlling the establishment of connections. Such signaling information is communicated over channels that are separated from the channels carrying actual voice or data communications between the connected customers. Among the components that need to communicate to establish voice and data communication links are the mobile units, the base station system connected by radio to the mobile units, the mobile switching center and the various databases that are consulted for the establishment of mobile calls. These databases include a home

location register (HLR) with an authentication center (AC (IS-41) or AuC (GSM)), a visitor location register (VLR), and an equipment identification register (EIR).

Signaling messages among these components are processed by many expensive protocol handlers. In the past, these protocol handlers were too expensive to permit incorporation into a single unit. Modern switching systems typically include expensive MSCs, such as AT&T's 5ESS® switch. These systems only make sense for deployment when there are a large group of mobile customers who will use the system.

This invention uses advanced signal processing, a novel method of structuring signal processing software and an enhanced home location register/visitor location register to provide multi-protocol, scaleable mobile telecommunications capability. The software architecture is specifically designed so that generic processing is used to the maximum extent possible to process signals and data related to different digital and analog protocols including GSM, TDMA, CDMA and AMPS, and proprietary protocols.

Figure 1a shows a general arrangement of a mobile telecommunications environment 100. At the heart of this environment 100 is an aircore platform 200 of the invention. The aircore platform 200 receives messages from, and transmits messages to a variety of fixed and mobile sources, conforming to each of the protocols employed by the sources.

Base transceiver stations (BTSs) 110 receive messages from and transmit messages to the aircore platform 200 over land lines 113. The land lines 113 may be any telecommunications medium that is capable of high speed data transmission, such as fiber optic cable, T-1 and E-1 lines and coaxial cable, for example.

The BTS 110 transmits messages to and receive messages from mobile and fixed sources. In Figure 1a, the BTSs 110 are shown in wireless communication with mobile phones 112, a mobile phone in a car 116 (a roaming mobile phone), a microcell 115, and a wireless local loop 150. The wireless local loop 150 may include

several connections. The wireless local loop 150 is described in more detail below. A telephone 118 may operate in conjunction with a private branch exchange (PBX).

The BTSs 110 may operate in conjunction with the fixed and mobile sources, according to one of several wireless protocols as set forth above.

The aircore platform 200 communicates with a public switched telephone network (PSTN) 120 via a wired path 121 and with a wireless network 130 via a signal path 131.

The aircore platform 200 also communicates with a satellite 141 via a satellite receiver 140.

Figure 1b shows a GSM wireless environment 101. The aircore platform 200 connects to the BTS 110 via a base station controller (BSC) 105. Mobile units 112, the roaming mobile phone 116, the wireless local loop 150 and the microcell 115 communicate by way of wireless radio channels with the BTS 110. The aircore platform 200 also connects to a GSM MAP network 133 via landline 132 and to the PSTN 120 via the landline 121. Finally, the aircore platform 200 communicates with the satellite 141 via the antenna 140.

Figures 1c and 1d show wireless environments 102 and 103, respectively. The wireless environment 102 is used with CDMA-protocol mobile units and base stations, and the wireless environment 103 is used with TDMA-protocol wireless units and base stations.

Figure 2 shows the aircore platform 200 in more detail. In Figure 2, the aircore platform 200 includes a mobile switching center (MSC) 210. The MSC 210 is configured such that the aircore platform 200 can receive and transmit multiprotocol wireless communications and wired communications with a variety of platforms. The MSC 210 may include a visitor location register (VLR). Alternately, the VLR may be separated from the MSC 210. The aircore platform 200 also includes a home location register (HLR) 212. The HLR 212 includes permanent information about customers who use the local environment serviced by the aircore platform 200. The data stored in the HLR 212 is the permanent data that is independent of the customer's

present location, plus temporary data stored such as the address of the system (may be signaling system 7 (SS-7) or other system) where the mobile unit is currently registered and the address of service centers that have short messages for a mobile unit. An example of such a short message is a request to turn on a voice message waiting lamp indicating that a voice message has been stored for the mobile unit's use in a voice messaging system. These addresses are erased after the short messages have been delivered. The signaling system 7 (SS-7) is described in detail in A.R. Modarressi, et al., "Signaling System No. 7: A Tutorial," *IEEE Communications Magazine*, July 1990, pp. 19-35.

The VLR contains the profile data for the mobile unit and the transient data for each mobile customer, including the mobile unit's present or most recently known location area, the mobile unit's on/off status, and security parameters.

An authentication center 213 is used to ensure that only properly authorized mobile and wired sources communicate through the aircore platform 200. The authentication center 213 provides authentication encryption parameters to ensure that a mobile customer cannot falsely assume the identity of another mobile customer and provides data for encryption of the voice data, and control signals transmitted via the air between the mobile unit and the servicing base station system. Encryption is desirable for the transmission of messages between the mobile unit and the radio transceiver at a base station serving that mobile unit because it is possible to listen in, or tap, the radio channels carrying voice communications.

An equipment identity register (EIR) 211 includes a database of the mobile equipment using the aircore platform 200, including specific protocols and equipment preferences. The EIR 211 retains the ranges of certified equipment identifications and the ranges of, or the individual equipment identifications that are under observation or barred from service. The equipment identification information is received from a mobile unit at the MSC 210. The EIR 211 is used to verify that the equipment number of the mobile unit is certified for use in the public network and is not on the observation or service barred list.

The MSC 210 is connected to other wireless network components and to the PSTN for accessing land-based customer stations and to the integrated services digital network (ISDN) for communicating according to ISDN protocols. A base station system (BSS) 104 may include the BSC 105 and one or more BTSs 110 for communicating with mobile units. The BSS 104 and the mobile units communicate via radio connections. The BSS 104 is also connected via trunks to carry the voice, data, and control messages between the mobile units and the MSC 210. The BSC 105 and the BTS 110 may be in different physical locations (for example, the BSC 105 may be co-located with the MSC 210 in which case a trunk is required to interconnect the two). This is done since the communications between the BTS 110 and the BSC 105 can typically be compressed to optimize the BTS connectivity requirements.

Figures 3 - 7 show different mobility architectures that can be used with the aircore platform 200. In Figure 3, the aircore platform 200 is shown communicating with the BTS 110. The BTS 110 may service the wireless local loop 150. The aircore platform 200 may also connect with the PSTN 120.

Figure 4 shows the aircore platform 200 used in conjunction with fixed wireless local loop customers. In Figure 4, the fixed wireless local loops 151 include a number of fixed customers in each of the local loops 151. The local loops 151 provide telephony services to fixed wireless customers in their respective loops. The services are provided via a fixed terminal (not shown) that is attached to a location and typically extends via a standard two-wire or similar connection to an analog telephone within the location. Call processing and feature management are handled by the aircore platform 200 as for a normal wireless customer. The only difference for the aircore platform 200 is that the area of operation for the fixed terminal does not change. Even though the terminal is using a wireless interface for communications, the terminal's location remains fixed. The aircore platform 200 processes the calls to and from the customer in the same manner as with mobile wireless calls because the air interface determines the protocol and the feature set that is to be used to communicate with the customer's fixed terminal. The protocol can be any of the

wireless protocols (CDMA, TDMA, AMPS, GSM). To limit the area of communications for a particular fixed terminal, the aircore platform 200 can be configured to only allow service to a particular location area for a particular fixed terminal.

The aircore platform 200 provides a full range of mobile services to a wireless local loop, or location area. In Figure 5, the aircore platform 200 is shown providing mobile services to a wireless local loop 152 and a wireless local loop 153. In this type of mobility situation, customers may move with their wireless terminals in a given wireless local loop or location area. Movement outside of the location area is not supported for these types of terminals. A typical implementation of this type of mobility is provided in a village or town scenario where the coverage is disjointed from other parts of the telecommunications system.

Figure 6 shows a system level mobility scenario that permits mobility for the customer across all location areas under the control of the local aircore platform 200. In Figure 6, the location area 154 and the location area 155 are both serviced by the aircore platform 200. Moreover, customers in the location area 154 may freely move through the location area 154 and the location area 155 and maintain wireless communications with the aircore platform 200. This type of scenario can be found in multiple towns or villages where a common aircore platform 200 is shared and the coverage is contiguous or there is a considerable amount of allowable travel between the locations covered by the system.

Figure 7 shows a full scale mobility scenario. In Figure 7, the aircore platform 200 communicates with a public land mobile network (PLMN) 158 and with local wireless loops 156 and 157. The local wireless loops 156 and 157 also communicate with the PLMN 158. This configuration provides for incoming and outgoing roaming traffic to and from the local aircore platform 200 to other switching centers, which may also be aircore platforms 200.

Figure 8 is a block diagram of a wireless network architecture according to the invention. In Figure 8, the aircore platform 200 includes a MSC/VLR 210', a home

location register 224, an authentication center 226, and an equipment identification register 225. The aircore platform 200 communicates with the base station system (BSS) 104' using one or more protocols including GSM, CDMA, TDMA, and AMPS. The aircore platform 200 also communicates with the PSTN 220 and other elements of the wireless network. An alternate mobile telecommunications switch is also shown in Figure 8. A MSC/VLR 210'' is coupled to the PSTN 220 and the BSS 104". However, other modular components used in the mobile telecommunications environment are located remotely from the MSC/VLR 210''. A system management controller 230, a home location register 221, an equipment identification register 222 and an authentication center 223 may be physically separated from the MSC/VLR 210''. However, the functions of these modular components remain the same, whether they are located with or remote from the MSC/VLR 210' and 210'', respectively.

Figure 9 shows the functions and connections of the aircore platform 200. In Figure 9, the visitor location register, the home location register, the equipment identification register and the authentication center are shown co-located with the MSC 210. The aircore platform 200 connects to the PSTN 120 via a T-1/E-1 line. The aircore platform 200 is adapted to receive land-line originated telephone messages. The aircore platform 200 can then send a connect message to an appropriate base station system. The aircore platform 200 also allows intersystem connection to an IS-41 wireless network 170 via a SS-7 link and a GSM wireless network 160 via a SS-7 link. Optionally, these links may be based on other communication carriage mechanisms such as IP, X.25, frame relay, or asynchronous transfer mode (ATM).

The aircore platform 200 provides for intrasystem, or base station, wireless communication using GSM protocols via a GSM BSC 240 and BTS 241. The aircore platform 200 provides wireless communications using CDMA and TDMA via a IS-634 link, an IS-95A BSC 244, a BTS 243 and a IS-136 BSC 242 and BTS 249. The aircore platform 200 communicates with an AMPS BTS 246 using the ISDN PRI+ or

the IS-634 protocol. The aircore platform 200 provides communications with a private branch exchange (PBX) 248 via T-1/E-1 lines. The aircore platform 200 also provides for connection to a billing system 260 using TCP/IP protocols, for example, and for voice mail and messaging functions via voicemail module 250.

TABLE A

TYPE	PROTOCOL	APPLICATION
Base Station	GSM "A" (Series 4 and 8)	GSM Network
	IS-651 & J-STD	US GSM based PCS
	IS-634 (IS-136)	DAMPS Network
	IS-634 (IS-95A)	CDMA Network
	IS-634 (AMPS)	Analog Network
	ISDN PRI+(AMPS)	Analog Network
Intersystem	GMS 09.02	GSM Network
	IS-652	US GSM based PCS
	ANSI-41	DAMPS, DCMA, AMPS Network
PSTN	T-1	T-1 Interface (various protocols) to the PSTN
	E-1	E-1 Interface (various protocols to the PSTN
Tandem	T-1	T-1 Interface tandem call traffic between local PBX and the PSTN
	E-1	E-1 Interface tandem call traffic between local PBX and the PSTN
Voice Mail	T-1	T-1 Interface to voice mail system
	E-1	E-1 Interface to voice mail system
Billing Center	TCP/IP	Interface for the transfer of Call Detail Records
NMC/OMC	TCP/IP	Interface for the exchange of Network Management related information

Table A shows a list of interfaces from the aircore platform 200 and the functionality each of the interfaces adds. A Network Management Center/Operations and Maintenance Center (NMC/OMC) 262 communicates with the aircore platform

200 using TCP/IP protocols, for example. The billing system 260 and the NMC/OMC 262 may also communicate with the aircore platform 200 using CCITT X.25 protocols.

Figure 10 is a block diagram of the aircore software architecture 300. In Figure 10, the architecture 300 is shown including a system control module SCM layer 310, a call processing control module handling the real time application layer 400, and a device handler layer 500. The SCM layer 310 maintains responsibility for non-real time related applications, such as report management and configuration. The SCM layer 310 generates and collects various types of report data, system configuration information and system maintenance procedures. The SCM layer 310 may be logically and physically separated from the rest of the aircore software architecture 300.

The call processing control module of the real time application layer 400 handles the application layer tasks that are real-time related. At the real time application layer 400 of software, direct knowledge of specific protocols is not required. Instead, this layer handles functions from a generic standpoint. For example, a call processing state machine processes mobile originated call set up in the same manner regardless of the type of interface used to connect to the base station equipment. The event set and state machine commonality allow lower layers of software to change without effecting the call processing control module of the real time application layer 400.

The device handler layer 500 is the lowest layer of software in the aircore software architecture 300. The device handler layer 500 contains the specific software applications to receive and transmit protocol specific messages.

The SCM layer 310 includes a control panel (CTL) 312, which is the father process of all the other processes in the system. The CTL 312 is responsible for startup and auditing of the overall aircore software architecture 300. Once started, the CTL 312 is only involved in limited auditing functions.

A call record management (SCR) 314 tracks the call report data generated in the system. These records can be used for billing tracking, system tendencies, or prepaid type of access. Call records are archived and the files rotated periodically. For example, the files may be rotated hourly. Real-time output is accessible via standard output options such as a printer or a screen output. Archived output is accessible on screen, or may be accessed over a standard TCP/IP network or dial up.

An operational measurements manager (OMM) 316 is responsible for tracking system counters. A count is defined as the occurrence of a particular situation. Each time the situation occurs, the counter is incremented. Operational measurements are archived and the files rotated periodically. For example, the files may be rotated hourly. Each time a new file is created, each of the counters is reset to zero. This type of data is captured to allow an operator to track system performance and tendencies over time. Operational measurements are archived into files rotated periodically. Real-time output is accessible using standard output options such as a printer or a screen output. Archived output is accessible on-screen or can be accessed over a standard TCP/IP network or dial up.

A real-time log report manager (RTL) 318 tracks system level reports. System level reports are generated to notify an operator of certain tasks or situations occurring on the aircore platform 200. For example, at the top of the hour, the system level audit log reports may be output. Log reports range from reporting normal system maintenance events to system status changes. Log reports are archived into files rotated periodically. Real-time output is accessible using standard output options such as a printer or a screen output. Archived output is accessible on screen or can be accessed over a standard TCP/IP network or dial up.

An auto removal process (AUTO) 322 is responsible for automatic removal of outdated archived report files. Automatic removal may occur on a periodic basis, such as monthly.

A network management database administration (NMS) 324 allows access to databases that provide configuration information for routing, rating and language for

mobile devices. A system configuration (SYSCFG) 326 allows access to the configuration of system telephony hardware resources. A system maintenance (SYSMTC) 328 allows access to operator-initiated maintenance procedures.

A visitor location register interface VLI 332 provides the operator access to a visitor location register. A home location register interface (HLI) 334 provides an operator interface to the home location register and authentication center information. An equipment identity register interface (EII) 336 provides an operator interface to the equipment identity register. The VLI 332, HLI 334 and EII 336 may be implemented as a graphical user interface(s) (GUI) or as batch type operations. These interfaces will be described in more detail later.

The call processing control module (CPCM) of the real time application layer 400 includes a recovery and startup (REC) 402, which is the father process of the software subsystems in the real time application layer 400 and at the device handler layer 500. The REC 402 manages the maintenance states for the trunk and signaling facilities in the real time application layer 400. The REC 402 interfaces with each of the device handlers in the device handler layer 500 for maintenance and status as well as with graphical user interface-based applications in the SCM layer 310 to process operator initiated maintenance requests. The REC 402 also initiates an audit of all real time application layer 400 subsystems. The audit may run every two minutes, for example, and provides assurance that all subsystems are running properly.

A fault analysis unit (FAU) 404 is responsible for the collection of all log reports and operational measurement related data created within the CPCM 400. The FAU 404 to real-time layer interface is a singular path for this information to pass. All CPCM 400 subsystems have access to pass events to the FAU 404 for this purpose.

The timer manager (TIM) 406 provides timing facilities to call processing control module subsystems in the aircore platform 200. The TIM 406 is used for application level timers that operate on a one second or greater granularity. Timers are stored in a list and are tracked until they are released or until they expire. Timers

requiring finer granularity or those that are specific to a particular subsystem's requirements are controlled locally either in the subsystem or on board in the hardware. The timers associated with the aircore platform 200 will be described later in more detail.

A resource manager (RCM) 408 is used to manage base station resources connected to the aircore platform 200. The RCM 408 has the capability to configure, download, and track the state of individual cell site components as well as the base station as a whole.

A CPCM call record management (CCR) 412 module provides for local collection of call detail record (CDR) information for calls in progress. When calls are completed, the CDR information is transferred from the CCR 412 to the SCR 314 in the SCM 310, where the call record data is processed and stored.

A call processing manager (CPM) 414 provides the processing required for all communication channel establishment, tear down, feature processing and hand off control. The state machines in place in the CPM 414 are based on a half-call model. Each party in a session moves through a defined set of states based on received and sent events, and timers used. Each side of a call steps through its own state. The two sides of the call progress together. For a basic call setup, the state of one side of the call is never more than one step ahead or behind the state of the other side. In the CPM 414, each call placed requires the creation of a session object. This object is created based on an index number created from the board span and channel used by the originator of the call. The session adds and removes call objects as dictated by the progress of the call. The reference number for the session is always based on the originator's board span and channel. However, the session may also be indexed via the index number of the board, span and channel of any of the involved parties.

A hand off processor (HOP) 416 is responsible for the preprocessing required for hand off or hand over (GSM). Based on the technology and the involvement of intersystem border cells, the level of involvement of the HOP 416 varies from one air interface protocol to the next. However, like other modules performing specific

functions, the unique aspects of the protocol are handled internally in the HOP 416. The interface to the CPM 414 for hand off processing is made generic. Preprocessing in relation to handoff processing refers to the collection of data and the decision process used to determine the appropriate base station to target for the hand off. This entire process has been formed into a generic procedure within the aircore software architecture 300.

A tone and announcement manager (TAM) 418 is responsible for management of the digital signal processor resources in the system used for playing tones and announcements. The TAM 418 interacts directly with the CPM 414 to provide the necessary digital signal processor allocations. The digital signal processors are controlled by components of the device handler 500. Direct communication to the device handler from the CPM 414 is avoided so that the CPM 414 does not have to maintain direct knowledge of the current digital signal processor configuration and allocations.

A visitor location register (VLR) 422 is responsible for establishing and maintaining a VLR database for the aircore platform 200. As shown in Figure 10, the VLR 422 is co-located with the aircore platform 200. However, the VLR 422 could be located remotely from the aircore platform 200. The VLR 422 is a collection of customer profiles for users currently active on the system. The VLR 422 is a dynamic database created and maintained while the aircore platform 200 is running. The VLR 422 communicates with threads inside an Advanced Intelligent Message Handler (AIM) 430, which will be described later, for real-time application messaging. Any communications to or from the VLR 422 from the CPCM 400 are received via the AIM 430. Communications with the VLI 332 are limited to those necessary to allow for the display of individual customer profile information, listing the current profiles in the VLR 422 and allowing an operator the ability to update customer profiles from the VLR database.

A home location register/authentication center (HLR) 424 is responsible for establishing and maintaining the HLR database for the aircore platform 200. As

shown in Figure 10, the HLR 424 is co-located with the aircore platform 200. However, the HLR 424 could also be located remotely from the aircore platform 200. In addition, the functions of the HLR 424 could be carried out in separate HLR and AC modules. The HLR 424 includes a collection of permanent customer profiles for users homed on the system. The HLR 424 is a static database that tracks the current location of a customer in addition to the individual profile parameters and status of customer-related features. The HLR 424 communicates with the AIM 430 for real-time application messaging. Any communications to or from the HLR 424 in the CPCM 400 are received via the AIM 430. Communications with the HLI 334 are limited to those necessary to allow for the manipulation of individual customer profiles, listing the current customer profiles in the HLR 424, and allowing an operator to update the customer profiles.

The HLR 424 also contains the functionality to perform the advanced security calculations used in digital air interface protocols. These calculations are based on a piece of secret data combined with a random number to yield a result that only has meaning to the authentication center and the mobile unit. This functionality is included in the HLR database and is integrated as part of the customer profile. The actual comparison of data is done in the AIM 430 or in the HLR 424 itself, depending on the protocol. Since the authentication center is integrated in the HLR 424, communications with the authentication center all funnel through the HLR 424. The authentication process will be explained in more detail later.

An equipment identity register (EIR) 426 is responsible for establishing and maintaining an EIR database for the aircore platform 200. The EIR database is a collection of the serial number information for mobile telephone handsets and other equipment in the system. The EIR 426 normally maintains at least three lists:

White - range listing of valid international mobile equipment identities (International Mobile Equipment Identity (IMEI)) (serial numbers).

Gray - list of individual serial numbers of questionable phones. Usage is operator dependent.

Black - list of individual serial numbers of equipment prohibited from using the system.

The EIR 426 is used with GSM-type systems. However, application to other system protocols may also be accomplished. The EIR 426 communicates with the AIM 430 for real-time application messaging. Any communications to or in the EIR 426 from the CPCM 400 are received via the AIM 430. Communications between the EIR 426 and the EII 336 are limited to those necessary to allow for the manipulation of list information. This includes allowing an operator to add, modify and delete from the information the EIR database.

The device handler 500 includes a portion of the AIM 430. The device handler 500 includes a device handler for digital CAS interface (DHD) 501, a device handler for voice input and output devices (DHA) 502, a device handler for ISDN interfaces (DHI) 503, a device handler for conference (DHC) 504, and a device handler for timers (DHT) 505. The AIM 430 also includes a device handler for SS-7 (DH-7) 510.

Figure 11 is a logical diagram of the advanced intelligent message handler (AIM) 430. The AIM 430 provides for advanced protocol processing, message routing and system interfaces for the wireless network. The AIM 430 is built around the steps required to establish call processing, mobility, and servicing in a wireless environment. The basic approach of the AIM 430 is to use a multi-thread system to isolate protocols and functions required for the mobility environment. Each different protocol family supported by the aircore platform 200 is handled by a thread specifically constructed for the message sent and state machine for that protocol.

Communications to various software entities such as the VLR, HLR, and EIR funnel through the AIM 430 subsystem. This approach is taken to remove the knowledge of the low layer message destination from each of those entities. This approach also allows for the isolation of protocol specifics to the AIM 430 layer of software. Finally, this approach allows for the seamless separation of these functions to physically separate entities without effecting the application software. The

following is an example of the benefit of this approach: When the CPM 414 needs to request the current location of a subscriber from the HLR 424, the message is sent to the AIM 430 subsystem without the direct knowledge of the HLR location or the protocol used to communicate with the HLR 424. The AIM 430 handles the routing (either internal or external) and the selection and construction of the appropriate message based on the protocol.

In Figure 11, a main AIM thread 438 is shown along with subordinate threads 431-436. In addition, a common memory 439 is used to share data related to a transaction or connection between the subordinate threads 431-436 and the device handler for SS-7 (DH-7) 510. Since each of the procedures followed for call establishment, location updating, etc., involve multiple threads and actions, the common memory 439 optimizes the performance of the AIM 430 by reducing the copying of data between threads while at the same time allowing data sharing across all of the threads by simply passing a pointer.

The A-interface message handler (AMH) 431 provides message decoding and encoding for interface processing between an external base station and the aircore platform 200 event structures and state machines.

Figure 12 is a block diagram of the logical architecture of the A-interface message handler AMH 431. Communications received from a base station interface are first interpreted by the AMH 431. The encoding and decoding specification for a particular protocol are contained in dynamic linked libraries 441 and 442 that are linked to the AMH 431. Each variant of the A-interface has its own unique set of builder/decoder dynamic linked libraries. Each type of A-interface utilizes its own instance of the AMH 431. Also shown in Figure 12 are timers 443_i through 443_n. The timers 443_i-443_n, which control operations of state machine call processing for a given connection, will be described in more detail later.

Figure 13 is a logical block diagram of the ISUP message handler (SMH) 436 logical architecture. The SMH 436 provides appropriate message conversion between the application programming interface and the internal aircore subsystem event

structures. As shown in Figure 13, the SMH 436 is logically linked to the board levels at boards 444_1-444_n.

Figure 14 is a logical block diagram of the intersystem message handler (IMH) 432 architecture. The IMH 432 encodes and decodes protocol messages related to a mobile unit from an external communications system. These messages are called Mobile Application Part. The encoding and decoding specifications for a particular protocol are contained in the dynamic linked libraries 445 and 446 that are linked to the IMH 432. Each variant of the MAP interface has its own unique set of builder/decoder dynamic linked libraries. Each type of MAP interface utilizes its own instance of the IMH thread 432. Also shown linked to the IMH thread are timers 447_1-447_n. The function of the timers 447 will be described in more detail later.

An authentication and registration processing (ARS) thread 434 (see Figure 11) provides appropriate calculations, comparisons and invocations of the required authentication for a given base station interface. A paging processing (PAG) thread 435 (see Figure 11) provides the processing necessary for paging in the AirCore system. Paging is the mechanism for locating and starting the process of notifying a mobile unit of an incoming call or message.

Figure 15 is a logical block diagram of the device handler for voice I/O devices (DHA) 502. The DHA 502 provides control of voice I/O resources in the aircore platform 200 that are used for playing tones and announcements. The DHA 502 is a single process that spawns individual threads for each digital signal processor that is accessible. As shown in Figure 15, the DHA 502 spawns digital signal processor threads 522_1 through 522_n. The aircore platform 200 uses the first five digital signal processors in the system to play standard tones. These tones are accessible to all ports on the system. This approach satisfies the requirements of playing ring-back or busy tones to all ports simultaneously. After the first five digital signal processors, the remaining digital signal processors are allocated to a pool that may be used in real-time call processing to play tones or announcements for call progressing. The five digital signal processors are used for the standard tones of ring

back, busy, fast busy, dial tone and confirmation beep. To play announcements for call progressing, the DHA 502 works with the tone and announcement manager (TAM) 418 (not shown, see Figure 10), which receives its commands from the CPM 414.

Figure 16 shows the device handler for digital channel associated signaling (CAS) interface (DHD) 501 in more detail. Channel associated signaling is a method of signaling in telecommunications where a portion of each channel between two entities is allocated for the carriage of the signaling and supervision in formations. The DHD 501 is a multi-thread, multi-process subsystem that provides for CAS processing.

Each channel in the DHD 501 is allocated a thread for processing the low layer protocol state machine. As shown in Figure 16, spans 511_1-511_n are associated with processing threads 512_1-$512_{24/32}$ and 513_1-$513_{24/32}$. The top layer process in the DHD 501 architecture is responsible for the interworking between the thread output in the real time application layer 400.

Figure 17 shows the device handler for ISDN interfaces (DHI) 503. The DHI 503 is a multi-threaded, single process subsystem that provides processing for common channel signaling interfaces. The DHI 503 is used internally in the aircore platform 200 to handle facilities (T-1 or E-1) that use common channel signaling methods. Common channel signaling provides a single signaling channel for the control of signaling and supervision information for many channels of resources (e.g., a single channel is used to pass the appropriate signaling for all of the associated traffic channels). Typically the signaling channel is based on an industry signaling method such as SS-7, LAPD, or TCP/IP. In the DHI 503, a top layer process is responsible for communications to the internal aircore platform 200 subsystems. Linked to the DHI 503 are board level threads 520_1-520_n. The board level threads 520_1-520_n are used to handle individual boards in the aircore platform 200.

Figure 18 is a logical block diagram of a device handler for SS-7 (DH-7) 510. The DH-7 510 exists for the purpose of handling the board level API for the SS-7

links in the system. The main tasks of the DH-7 510 are the basic assignment of threads to the SS-7 links and assuring proper message routing for inbound messages to the internal aircore subsystems and threads. Each SS-7 link established in the system has its own link level thread that exists as a subordinate thread to the main DH-7 510 thread.

Figure 19 is a logical block diagram showing interlayer communications among the SCM layer 310, the real time application layer 400 and the device handler layer 500. In Figure 19, a two-way communications path 350 between the CTL 312 and the REC 402 is used to start the real time application layer 400 and report the appropriate status information. One-way path 351 is used to transfer CDRs from the real time application layer 400 to the SCM layer 310. One-way path 352 between the FAU 404 and the RTL 318 is used to transfer report and operational measurement pegs from the real time application layer 400 to the SCM layer 310. One-way path 353 between the SYSMTC 328 and the REC 402 is used to pass maintenance related commands to the real time application layer 400 from the SCM layer 310. Two-way path 354 from the VLI 332 to the VLR 422 is used to exchange information between the VLR 422 and the VLR graphical user interface 332. Two-way path 355 between the HLI 334 and the HLR 424 is used to exchange information between the HLR 424 and the HLR graphical user interface 334. Two-way path 356 between the EII 336 and the EIR 426 is used to exchange information between the EIR 426 and the EIR graphical user interface 336.

Path 450 between the REC 402 and subsystem at the device handler layer 500 is defined for startup, status and maintenance communications used to interact with the telephony board level hardware. The REC 402 communicates directly with all device handler level subsystems with the exception of the DH-7 510, which is handled via communications with the AIM 430. Two-way path 451 between the CPM 414 and the device handler layer 500 is established for the exchange of messages for call processing related activities in the aircore platform 200. The CPM 410 communicates directly with all device handler 500 level subsystems with the exception of the DHA

502 and the DH-7 510. Communications path 452 between the TAM 418 and the DHA 502 provides for the allocation and deallocation of voice I/O resources for tones and announcements. Much like trunk groups that abstract the physical location of trunks, this level of communication abstracts the physical location of the digital signal processors used for playing the tones and announcements. Communications path 453 between the AMH 431, SMH 436, IMH 432 and the DH-7 510 provides for communications between the SS-7 links and the builder/decoder threads in the AIM 430.

Figure 20 is a logical representation of the HLR 424. The HLR 424 contains permanent data that is independent of the customer's present location, plus temporary data such as the current location of the system where the mobile unit is registered and the addresses of service centers that have stored short messages for mobile stations. An example of such a message is a request to turn on a voice message waiting lamp indicating that a voice message has been stored for the mobile station user in a voice messaging system. These addresses are erased after the short messages have been delivered.

As shown in Figure 20, the HLR 424 includes customer profiles 460_i for each mobile customer. The customer profile 460_1 includes a customer data module 461. The customer data module 461 includes a customer group identification, which is a four digit number specifying the routing translations index for the customer. The number must be previously configured in a routing translations data base via a routing administration window. The customer data module 461 also includes the International Mobile Customer Identity (IMSI), the International Mobile Equipment Identity (IMEI) or Electronic Serial Number (ESN), which is the serial number of the handset hardware, and the K_i, or A-key which is the key used for authentication calculations. The customer data module 461 also includes the name of the customer, the language for customer announcements, a three to five digit carrier ID identifier for long distance carrier code associated with the customer, a check box for calling card features and a prepaid feature. A call offering module 462 includes an indication of current features

such as call forwarding unconditional (CFU), call forward busy (CFB), call forwarding no reply (CFNRy), and call forwarding not reachable (CFNRc), and call forwarding default (CFD).

A VLR/MSC data module 463 indicates the VLR in and the MSC associated with the current area of operation of the customer. A personal identification number (PIN) data module 464 indicates if the customer uses a PIN when accessing the system for calling card or long distance calls and the four digit PIN number associated with the customer. A protocols module 465 is used for multi-mode customers to determine the capabilities of the customers' units. The protocols may include, but are not limited to, TDMA, CDMA, GSM and AMPS. A call restriction module 466 stores features for restricting the calling capabilities of the customer to and from the network. The call restriction features include baring of all outgoing calls, suspended service (no calls allowed), baring of all outgoing international calls, baring of all incoming calls, baring of all outgoing international calls except those to the home PLMN country and baring incoming calls to a customer when they are roaming to another system.

A call features module 467 indicates the set of features allocated to a customer. The call features include call hold, multi-party calling, 3-way calling, roaming, call waiting and access to sending and receiving short messages. A line identification module 468 identifies features that provide/restrict calling and called number information to various parties in a call. The line identification features include calling line ID presentation, calling number presentation, connected line ID presentation, calling line ID restriction, calling number restriction, and connected ID restriction.

A message center data module 469 provides for storage of short messages pending delivery to a customer's mobile unit.

The HLR 424 may also include an authentication center. The authentication center provides authentication and encryption parameters to insure that a mobile customer cannot falsely assume the identity of another mobile customer. The

authentication center also provides data for encrypting the voice or data and control signals transmitted via the air between the mobile station and the serving base station subsystem. A GSM reference model prescribes digital communications over the radio channels. Since it is possible to surreptitiously listen to these channels, encryption becomes desirable for the link between the mobile station and the radio receiver at a base station serving that mobile station. Any public or proprietary encryption algorithm known in the art can be used with the aircore platform 200.

The calculations for the authentication center use the secret key information associated with the subscriber and the protocol specific calculations. The HLR 424 pre-processes these authentication calculations and stores them as part of the subscriber profile. As required, this information is shared with the servicing MSC/VLR to authenticate the mobile unit as it accesses the system.

The VLR 422 contains current data for each active mobile customer, including that customer's mobile station present or most recently known location area, the mobile unit's on/off status, and security parameters. The VLR 422 is logically constructed in the same manner as the HLR 424.

The HLR and VLR databases both simultaneously accommodate customer profiles from any interface protocol. There are two significant classifications of profile types, based on the intersystem protocol used to transmit and receive profile information over the wireless network. Both GSM and IS-41 based networks share common information in the customer profile structures, but each profile type also requires fields and information that are unique to that particular protocol type. The HLR and VLR databases provide for this by an internal structure that uses a common top level header for the common data and then protocol specific attachments. This internal structure is shown in Figure 21. A GSM side 417 and an IS-41 side 419 are used with the VLR and HLR databases. A common data header 427 is used for both GSM and IS-41 profile information. A GSM specific data area 428 is used for GSM specific data. An IS-41 specific data area 429 is used for IS-41 specific data. The common data header 427 allows the two sides of the database to use common search

routines while the specific data areas allows for the storage of data that pertains to a specific protocol alone.

A description of the timers used by the MSC 210 will now be provided. A call proceeds from initiation to connection through a series of steps. The time associated with this call set up and connection is usually short. Nonetheless, one or more voice channels may be reserved at the start of the call set up. If the call will not connect, some mechanism is desirable to release these resources as quickly as possible so that they may be used by other customers. Furthermore, during the time that the mobile unit is held waiting for an incoming call, the mobile unit cannot call out or receive other incoming calls. To free up resources and to release the mobile unit, the TMR 437, in conjunction with the TIM 406 (see Figure 10) includes a number of timers that may be established at various points in the call set up and connect process. The timers are generally set based on a message from the AMH 431 or similar interface.

A timer may be set when a device handler such as the device handler 510 requests a BSC 105 to assign a channel. In this case, the AMH 431 sends a message to the TMR 437 to set the timer. If an assignment is not completed within the time limit of the timer, the call connection process ends. If the assignment is completed before expiration of the timer, the AMH 431 sends a message to the TMR 437 to release the timer.

A timer may be associated with a connect message sent to the BSC 105 by a device handler. If a connect acknowledgment message is received by the device handler, the AMH 431 will send a timer release message, allowing the call connection to complete. Similarly, a timer may be set to time out a make call command, a paging message for a mobile terminated call, a disconnect message (GSM) or release message IS-634) for PSTN and mobile originated calls, and a clear command to release a channel during a call disconnect sequence. Other timers may be used to ensure resources are returned for assignment to other calls.

Managing the location of a customer ensures the proper connection of the customer's mobile unit for both mobile initiated calls and mobile terminated calls. In

Figure 22, the authentication and registration (ARS) 434 thread is shown in communication with the common memory 439. The common memory 439 includes the data relevant to the mobile unit and the state machine relevant to the protocol and the transaction being performed. The ARS 434 maintains communications with the AMH 431 and the IMH 432 to track ongoing transactions, to compare SRES, to send TMSI to the mobile unit and to provide ciphering information to the AMH 431. The IMH 432 provides connections to the VLR 422 and HLR 424 for obtaining customer profile information.

The call processing module (CPM) 414 processes calls according to one of several state machines. A state machine exists for each half of every call processed through the aircore platform 200. A separate state machine exists for mobile originated call processing, PSTN originated call processing and mobile terminated call processing, for example. Figures 23-25 are examples of state machines used in processing calls at the aircore platform 200. Figure 23 is a state machine 600 for mobile originated call processing. In Figure 23, eight states are possible: idle (S1), wait for UUI (S2), wait for page response (S3), wait for alert (S4), wait for connect (S5), voice (S6), wait for handoff confirm (S7), tone and announce (S8), and wait for call cleared (S9). The state machine 600 shows the allowed transitions between states. Starting in idle S1, the state machine 600 can transition to state wait for UUI S2 or wait for call cleared S9. The state machine 600 transitions to wait for UUI S2 based on reception of the mobile customer's profile when a CALL_RECEIVED message is received. The state machine 600 transitions from idle S1 to wait for call cleared S9 based on the mobile customer profile indicating a particular call restriction or if the call fails before routing. With the authentication previously set up with the A-interface protocol, this transition may not be possible.

In the wait for UUI state S2, the state machine 600 can transition to the wait for alert state S4. This transition is based on receiving the ROUTE_CALL message. The aircore platform 200 proceeds with making the call out to the called party if the call type is direct dial (DD) in the routing translations or when a call delivery to a

mobile unit or another system is required. The CPM 414 then sends a MAKE_CALL message. Next, the state machine 600 can transition from the wait for UUI state S2 to the wait for page response S3 based on receiving a ROUTE_CALL message. A PAGE_MOBILE message is sent to the PAG 435. The transition to this state is based on a call type of MOB in the routing translations and finding that the called mobile unit is operating in the aircore system. The state machine 600 transitions from the wait for UUI state S2 to the tone and announce state S8 if the dialed number received from the originating mobile unit fails to translate properly or if there is a restriction on the called mobile unit. The originating mobile unit is then connected to a tone. This transition could also occur by the CPM 414 receiving a PAGE_RESPONSE message with a time out indication. Finally, the wait for UUI state S2 can transition to the wait for call cleared state S9 based on receiving a disconnect from the mobile unit. When the message CALL_DISCONNECTED is received at the CPM 414, a CLEAR_CALL message is sent.

The state machine 600 transitions from the wait for page response S3 to the wait for alert state S4 based on receiving a PAGE_RESPONSE message. A MAKE_CALL message is then sent and the CPM 414 proceeds with an ISDN state machine 600. The wait for page response state S3 transitions to the tone and announce state S8 along transition path T8 based on receiving a time out for a page response. The CPM 414 then provides a time out announcement or tone to the calling party. The state machine 600 transitions from the wait for page response state S3 to the wait for call cleared state S9 along transition path T9 based on receiving a disconnect from the originating mobile unit. A CALL_DISCONNECTED message is received at the CPM 414 and a CLEAR_CALL message is sent. The PAG thread 435 will time out and clear the page request data for the call.

The state machine 600 transitions from the wait for alert state S4 to the wait for connect state S5 along transition path T10 based on receiving an alerting indication from the called party. The alerting indication is passed to the mobile customer's side of the call. The CPM 414 receives the CALL_ALERTING message

from the called party and sends an ALERT_CALL to the originating mobile unit. The transition from the wait for alert state S4 to the voice state S6 occurs along transition path T11 based on receiving a connect indication from the called party. The protocol allows a CONNECT message to be received without receiving alerting. The CPM 414 receives a CALL_CONNECTED message from the called party and sends a CONNECT_CALL message to the originating mobile unit. The transition from the wait for alert state S4 to the tone and announce state S8 is along transition path T12. This transition occurs for two possible reasons. First, the transition may be based on a time out waiting for the alerting indication. The called party is cleared from the call and the mobile customer is connected to an announcement or tone. The CPM 414 sends a CLEAR_CALL message to the called party. Second, the transition may be based on receiving a disconnect from the called party with "user busy." The originating mobile unit is sent an announcement and the called party is released from the call. The CPM 414 receives a CALL_DISCONNECTED message from the called party and sends a CLEAR_CALL message to the called party. Finally, the transition from the wait for alert state S4 to the wait for call cleared state S9 occurs along transition path T13 if the originating mobile customer disconnects from the call before the CPM 414 receives the alerting indication from the called party. Clearing both parties is initiated. The CALL_DISCONNECTED message is received from the originating mobile unit. The CPM 414 sends a CLEAR_CALL message to both parties.

The state machine 600 may transition from the wait for connect state S5 to the voice state S6 along transition path T14 based on receiving connect indication from the called party. The connect indication is passed to the mobile customer. The CPM 414 received a CALL_CONNECTED message from the called party and sends a CONNECT_CALL message to the originating mobile unit. Transition from the wait for connect state S5 to the tone and announce state S8 occurs when a time out occurs waiting for the connect. The called party is cleared from the call and the mobile customer is connected to a tone or announcement. The CPM 414 sends a

CLEAR_CALL message to the called party. Transition from the wait for connect state S5 to the wait for call cleared state S9 occurs along transition path T16 if the originating mobile subscriber disconnects from the call before the CPM 414 receives the connect indication from the called party. Clearing both parties is initiated. The CPM 414 receives a CALL_DISCONNECT message from the originating mobile unit and sends a CLEAR_CALL message to both parties.

The state machine 600 transitions from the voice state S6 to the wait for called clear state S9 along transition path T17 based on receiving a disconnect indication from either party. Call clearing is initiated for both parties on the call. A CALL_DISCONNECTED message is received from one of the parties. The CPM 414 sends a CLEAR_CALL message to both parties. Transition from the voice state S6 to the wait for hand off confirm state S7 occurs along transition path T18 based on receiving a hand off request from the HOP 416 subsystem and having a B-channel to allocate to the target BTS for the hand off. The CPM 414 receives a HAND_OFF request from the HOP 416 and sends a MAKE_CALL message with a hand off indicating to establish the target channel. Finally, the voice state S6 transitions back to the voice state S6 along transition path T19 based on receiving a hand off request and not having a B-channel available to the BTS.

The state machine 600 transitions from the wait for hand off confirm state S7 to the voice state S6 along transition path T20 based on three possible events. First, the CPM 414 receives a hand off confirmation from the serving BTS. This indicates the mobile unit has confirmed the hand off and is in transition to the target BTS. The voice connection is switched to the target BTS at this point. The CPM 414 receives a HAND_OFF_CONFIRM message and sends a CLEAR_CALL to the old serving channel. The voice path in connected to silence until the CALL_CONNECTED message is received on the target channel. Second, the CPM 414 receives a hand off confirmation with a negative indication (failed). This indicates that the mobile unit is not going to the target channel. The CPM 414 starts a disconnect sequence to release the target channel. The CPM 414 then sends a CLEAR_CALL message to the target

channel. Third, the CPM 414 receives a failure on the channel setup with the target BTS. The transition to the voice state S6 occurs and the CPM 414 initiates or continues with the disconnect sequence with the target BTS channel. The CPM 414 sends a CLEAR_CALL message to the target channel. Transition from the wait for confirm state S7 to the wait for call cleared state S9 occurs along transition path T21 based on receiving a disconnect from either party while a target BTS channel is being established for the hand off. The CPM 414 initiates clearing all resources and transition. The CPM 414 receives a CALL_DISCONNECTED message and sends a CLEAR CALL message to the parties.

The state machine 600 transitions from the tone and announce state S8 to the wait for call clear state S9 along transition path T22 based on the originating mobile unit disconnect indication being received from the CPM 414. This can occur as a result of a time out after the tone or an announcement is played and a disconnect is not received. In this case, the CPM 414 initiates the disconnect with the mobile customer. The CPM 414 initiates the disconnect with the mobile customer. The CPM 414 either receives a CALL_DISCONNECTED message and sends a CLEAR_CALL message or the CPM 414 receives a time out and sends a CLEAR_CALL message.

The state machine 600 transitions from the wait for call cleared state S9 to the idle state S1 along transition path T23 based on both parties confirming they are cleared from the call. In cases where there is no other party involved in the call, the confirmation of the clearing of the party is implied by the fact that the cell never existed. This transition takes place when the call is completely cleared. The CPM 414 receives a CALL_CLEARED message from the originating mobile unit.

Figure 24 is a state machine 601 for PSTN originated call processing. In the state machine 601, the wait for UUI state S2 and the wait for handoff confirm state S7 are not allowed states. The state machine 601 transitions from the idle state S1 to the wait for page response state S3 along transition path T24 based on determining the need to page the mobile customer. The CPM 414 sends a PAGE_MOBILE message to the PAG thread 435. Transition from the idle state S1 to the wait for alert state S4

occurs along transition path T25 based on determining that the mobile customer is located on another system and the aircore platform 200 has received a routing number to call the current serving switch. The CPM 414 sends a MAKE_CALL message using the TLDN (MSRN GSM). The transition from the idle state 51 to the wait for alert state 54 can also occur under a forwarding condition of the original destination number. Transition from the idle state S1 to the tone and announce state S8 occurs along transition path T26 if the called number received from the originating PSTN party fails to translate properly or if there is a restriction on the called mobile unit. In this case the originating PSTN party is connected to a tone or announcement. This transition could also occur by the CPM 414 receiving a PAGE_RESPONSE message with a time out indication.

The state machine 601 transitions from the wait for page response state S3 to the wait for alert state S4 along transition path T27 based on receiving a PAGE_RESPONSE message. The CPM 414 sends a MAKE_CALL message and proceeds with the ISDN state machine. Transition from the page response state S3 to the tone and announce state S8 occurs along transition path T28 based on receiving a time out for a page response (i.e., PAGE_RESPONSE message received by the CPM 414 with a time out indication). The CPM 414 provides a time out announcement or tone to the calling party. Transition from the wait for page response state S3 to the wait for call cleared state S9 occurs along transition path T29 based on receiving a disconnect from the originating PSTN party. The CPM 414 receives a CALL_DISCONNECTED message and sends a CLEAR_CALL message. The PAG thread 435 will time out and clear the page request data for the call.

The state machine 601 transitions from the wait for alert state S4 to the wait for connect state S5 along transition path T30 based on receiving an alerting indication from the called party. The alerting indication is passed to the PSTN side of the call. The CPM 414 received a CALL_ALERTING message from the called party and sends an ALERT_CALL message to the originating PSTN party. Transition from the wait for alert state S4 to the voice state S6 occurs along transition path T31 based

on receiving a connect indication from the called party. The protocol allows reception of the connection without receiving alerting. The CPM 414 receives a CALL_CONNECTED message from the called party and sends a CONNECT_CALL to the originating PSTN party. Transition from the wait for alert state S4 to the tone and announce state S8 occurs along transition path T32 for two possible reasons. First, transition may be based on a time out waiting for the alerting indication. The called party is cleared from the call and the PSTN party is connected to an announcement or tone. The CPM 414 sends a CLEAR_CALL message to the called party. Second, transition may be based on receiving a disconnect from the called party with "user busy." The originating PSTN party is sent an announcement and the called party is released from the call. The CPM 414 receives a CALL_DISCONNECTED message from the called party and sends a CLEAR CALL message to the called party. Transition from the wait for alert state S4 to the wait for call cleared state S9 occurs transition path T33 if the originating PSTN party disconnects from the call before the CPM 414 receives the alerting indication from the called party. Clearing of both parties is initiated. The CPM 414 receives a CALL_DISCONNECTED message from the originating PSTN party and sends a CLEAR_CALL message to both parties.

The state machine 601 transitions from the wait for connect state S5 to the voice state S6 along transition path T34 based on receiving connect indication from the called party. The connect indication is passed to the PSTN party. The CPM 414 receives the call connected message from the called party and sends the CONNECT_CALL message to the originating PSTN party. Transition from the wait for connect state S5 to the tone and announce state S8 occurs along transition path T35 when a time out occurs waiting for the connect. The called party is cleared from the call and the PSTN party is connected to a tone or announcement. The CPM 414 sends a CLEAR_CALL message to the called party. Finally, transition from the wait for connect state S5 to the wait for call cleared state S9 occurs along transition path T36 if the originating PSTN party disconnects from the call before the CPM 414 receives the connect indication from the called party. Clearing both parties is

initiated. The CPM 414 receives a CALL_DISCONNECTED message from the originating PSTN party and sends the CLEAR_CALL message to both parties.

The state machine 601 transitions from the voice state S6 to the wait for call cleared state S9 along transition path T37 based on receiving a disconnect indication from either party. Call clearing is initiated for both parties. The CPM 414 receives the CALL_DISCONNECTED message from one of the parties. The CPM 414 then sends the CLEAR_CALL message to both parties.

The state machines 601 transitions from the tone and announce state S8 to the wait for call cleared state S9 along transition path T38 based on the originating mobile unit disconnect indication being received from the CPM 414. This can also occur as a result of a time out after the tone or announcement is played and a disconnect is not received. In this case, the CPM 414 initiates the disconnect with the mobile customer. The CPM 414 either receives a CALL_DISCONNECTED message and sends a CLEAR_CALL message or the CPM 414 receives a time out and sends the CLEAR_CALL message.

The state machine 601 transitions from the wait for call cleared state S9 to the idle state S1 along transition path T39 based on both parties confirming they are cleared from the call. In cases where there is no other party involved in the call the confirmation of the clearing of the party is implied by the fact that it never existed. Transition takes place when the call is completely cleared. The CPM 414 receives the CALL_CLEARED message from the originating mobile unit.

Figure 25 shows a state machine 602 for a mobile terminated call processing. As shown in Figure 25, the states wait for UUI S2, wait for page response S3 and tone and announce S8 are not used in a mobile terminated call processing scenario. The state machine 602 transitions from the idle state S1 to the wait for alert state S4 along transition path T40 based on reception of a valid PAGE_RESPONSE message. The CPM 414 sends a MAKE_CALL message to the terminating mobile unit. The idle state S1 returns to the idle state S1 along transition path T41 based on a page time out,

or failure in routing. The calling party is sent to an announcement or the call is forwarded based on the customer's feature profile.

State machine 602 transitions from the wait for alert state S4 to the wait for connect state S5 along transition path T42 based on receiving an alerting indication from the terminating mobile customer. The alerting indication is passed to the calling party's side of the call. The CPM 414 receives a CALL_ALERTING message and sends a ALERT_CALL message to the calling party. Transition from the wait for alert state S4 to the voice state S6 occurs along transition path T43 based on receiving a connect indication from the called mobile unit. The protocol allows receipt of a receive connect message without receiving alerting. The CPM 414 receives a CALL_CONNECTED message from the called party and sends a CONNECT_CALL message to the calling party. Transition from the wait for alert state S4 to the wait for call cleared state S9 occurs along transition path T44 if the calling party disconnects from the call before the CPM 414 receives the alerting indication from the mobile customer. Clearing both parties is initiated. The CPM 414 receives a CALL DISCONNECTED message from the calling party and sends a CLEAR_CALL message to both parties. In addition, in time out cases where the calling party is sent to an announcement, the called mobile unit will receive a CLEAR_CALL message from the CPM 414 and make the transition.

The state machine 602 transitions from the wait for connect state S5 to the voice state S6 along transition path T45 based on receiving a connect indication from the called mobile customer. The connect indication is passed to the calling party. The CPM 414 receives a CALL_CONNECTED message and sends a CONNECT_CALL message to the calling party. Transition from the wait for connect state S5 to the wait for call clear state S9 occurs along transition path T46 that the calling party disconnects from the call before the CPM 414 receives the connect indication from the mobile customer. Clearing both parties is initiated. The CPM 414 receives a CALL_DISCONNECTED message from the calling party. The CPM 414 then sends a CLEAR_CALL message to both parties. In addition, in time out cases where the

calling party is sent to an announcement, the called mobile unit will receive a CLEAR_CALL message from the CPM 414 and make the transition.

The state machine 602 transitions from the voice state S6 to the wait for call cleared state S9 along transition path T47 based on receiving a disconnect indication from either party. Call clearing is initiated for both parties in the call. The CPM 414 receives a CALL_DISCONNECTED message from one of the parties and sends a CLEAR_CALL message to both parties. Transition from the voice state S6 to the wait for hand off confirm state S7 occurs along transition path T48 based on receiving a hand off request from the HOP subsystem 416 and having a B-channel to allocate to the target BTS for the hand off. The CPM 414 receives a hand off request message from the HOP 416 and sends a MAKE_CALL message with a hand off indication to establish the target channel. Transition from the voice state S6 back to the voice state S6 occurs along transition path T49 based on receiving a hand off request and not having a B-channel available to the BTS.

The state machine 602 transitions from the wait for hand off confirm state S7 to the voice state S6 along transition path T50 in one of three situations. First, the CPM 414 receives a hand off confirmation from the serving BTS. This indicates the mobile unit has confirmed the hand off and is transitioning to the target BTS. Voice connection is switched to the target BTS at this point. The CPM 414 receives the HANDOFF_CONFIRM message and sends the CLEAR_CALL message to the old serving channel. The voice path is connected to silence until the CALL_CONNECTED message is received on the target channel. Second, the CPM 414 receives a hand off confirmation with a negative indication (failed). This indicates that the mobile unit is not going to the target channel. A disconnect sequence to release the target channel is started and the CPM 414 sends a CLEAR_CALL message to the target channel. Third, the CPM 414 receives a failure of the channel set up with the target BTS. Transition to the voice state S6 in initiation or continuation of the disconnect sequence with the target BTS channel begins. The CPM 414 sends a CLEAR_CALL message to the target channel. Transition from the hand off confirm

state S7 to the wait for call cleared state S9 occurs along transition path T51 based on receiving a disconnect from either party while a target BTS channel is being established for the hand off. The CPM 414 initiates clearing all resources and transition. The CPM 414 receives a CALL_DISCONNECTED message and sends a CLEAR_CALL message to all parties.

The state machine 602 transitions from the wait for call cleared state S9 to the idle state S1 along transition path T52 based on both parties confirming they are cleared from the call. In cases where there is no other party involved in the call, the confirmation of the clearing of this party is implied by the fact that a call never existed. This transition takes place when the call is completely cleared. The CPM 414 receives a CALL_CLEARED message from the originating mobile unit.

The aircore platform 200 uses a common facility state machine for tracking the states and conditions of external connections or trunks. Two portions of the state are tracked. Each facility has a near end and a far end state. The near end state represents the internal aircore state for the facility. The far end state represents the state of the facility as reported by the connected system. This state machine tracking applies to all aircore interfaces including traffic channels and signaling channels. Like call processing, these maintenance procedures are generic in the aircore platform 200 regardless of the interface.

Figure 26 is a aircore near end facility maintenance state machine 604. The state machine 604 includes the states not configured (S10), blocked (S11), unblocked pending (S12), unblocked (S13), call processing (S14), blocked pending (S15), and maintenance (S16).

Figure 26 also shows the transitions between the states of the state machine 604. The state machine 604 transitions from the state not configured S10 to the blocked state S11 along transition path T60 when a facility is added to the configuration and is enabled.

The state machine 604 transitions from the blocked state S11 to the unblocked pending state S12 over transition path T61 when either operator initiated or automatic

recovery occurs which requests that the destination device handler bring the requested facility to an unblocked (in service) state. Transition from the blocked state S11 to the maintenance state S16 occurs along transition T62 when the facility is taken to a maintenance state to perform a maintenance or test operation. This transition is based on an operator action. Transition from the blocked state S11 to the not configured state S10 occurs along transition path T63 when the facility is disabled and/or removed from the system configuration.

The state machine 604 transitions from the unblocked pending state S12 to the unblocked state S13 over transition path T64 when a maintenance action is confirmed by the device handler. The facility is now in service. Transition from the unblocked pending state S12 to the blocked pending state S15 occurs over transition path T65 when a maintenance action is denied by the device handler or aborted by an operator action.

The state machine 604 transitions from the unblocked state S13 to the call processing state S14 along transition path T66 when the facility is allocated and will be used for call processing. Transition from the unblocked state S13 to the blocked pending state S15 occurs along transition path T67 when either operator initiated or automatic maintenance action from the device handler. Transition also occurs based on other internal action requests that the destination device handler bring the requested facility to a blocked (off-line) state.

The state machine 604 transitions from the call processing state S14 to the unblocked state S13 over transition path T66 when the facility is released from being used in call processing. Transition from the call processing state S14 to the blocked pending state S15 occurs over transition path T69 when a maintenance action is either operator initiated or automatic from the device handler or other internal action requests that the device destination handler bring the requested facility to a blocked (off-line) state.

The state machine 604 transitions from the blocked pending state S15 to the blocked state S11 over transition path T70 when a maintenance action to take facility

off-line is confirmed by the device handler. In a case where the device handler does not respond, the state may be reached by default of no response.

The state machine 604 transitions from the maintenance state S16 to the blocked state S11 over transition path T71 when the maintenance action on the facility is completed. Operator action is required to transition the state back to the blocked state S11.

In addition to monitoring the near end state of the system facilities, the aircore platform 200 also maintains the far end state of facilities where applicable. The far end state represents the status of a facility at the connected system side. The far end state and near end state are used together to determine the overall operational state.

Figure 27 shows the aircore far end facility maintenance state machine 605. In Figure 27, the states are not configured (S17), blocked (S18), unblocked (S19), and unknown (S20).

The state machine 605 transitions from the not configured state S17 to the blocked state S18 along transition path T80 when a facility is added to the configuration and enabled.

The state machine 605 transitions from the blocked state S18 to the unblocked state S19 over transition path T81 when an unblocking request is received from the far end. Confirmation is then sent back with an unblocking acknowledgment message. Transition from the blocked state S18 to the unknown state S20 occurs over transition path T82 when a discrepancy has been detected between the state reported by the far end and the stored far end state for the facility in aircore platform 200. The blocked state S18 transitions to the not configured state S17 over transition path T83 when the facility is disabled and/or removed from the system configuration.

The state machine 605 transitions from the unblocked state S19 to the blocked state S18 over transition path T84 when a blocking request message is received from the far end. Confirmation is sent back with the blocking acknowledgment message. Transition from the unblocked state S19 to the unknown state S20 occurs over

transition path T85 when a discrepancy has been detected between the state reported by the far end and the stored far end state for the facility in the aircore platform 200.

The state machine 605 transitions from the unknown state S20 to the blocked state S18 over transition path T86 when the far end reports the state of the facility is blocked. Transition from the unknown state S20 to the unblocked state S19 occurs over transition path T87 when the far end reports the state of the facility is unblocked.

Hand off processing occurs when an active mobile unit transitions from a wireless region supported by one base station to a wireless region supported by a second base station. Hand off processing may also occur as a mobile unit transitions from one cell site within a wireless region to another sell site.

Figure 28 shows an aircore wireless environment 106 in which the aircore platform 200 functions as a mobile switching center (MSC). There are many different protocol scenarios that are possible for hand off processing in the aircore environment 106, including ISDN PRI+ with an AMPS base station, DHD-based (AMPS) base station, IS-634 AMPS, IS-634 TDMA, IS-634 CDMA, GSM, IS-41 Revision B, IS-41 Revision C and GSM mobile application part (MAP). In addition, the processing design of the aircore platform 200 retains the flexibility to easily adapt to other hand off protocols. Finally, the aircore platform 200 may receive hand off requests from multi-protocol mobile units.

In Figure 28, base station controllers (BSCs) 105_1, and 105_2 and base transceiver stations (BTSs), are shown connected to the aircore platform 200 via signal lines 485 and 495, respectively. The BSC 105_1 has an associated wireless region 480 that includes BTSs 481, 482 and 483. The BSC 105_2 has an associated wireless region 490 with BTSs 491, 492 and 493. The mobile unit 112 is active in the wireless region 480 at point A and communicates with a land-line phone 114 via PSTN 120, the aircore platform 200, the BSC 105_1 and the BTS 481.

In the above description, the BTS receives a call from a mobile unit. The mobile unit may be a mobile telephone or a computer with a wireless modem, for

example. In addition, the BSC/BTS may be replaced in some scenarios with a BSS or any other base station configuration.

During the course of a call, the mobile unit 112 transitions from point A in wireless region 480 to point B in wireless region 490. As a result of this transition, the BTS 105_1 detects that the signal level of the cell has dropped below the minimum to continue the call on the current channel. The BSC 105_1 notifies the aircore platform 200, which begins hand off processing to establish a new cell site using the BSC 105_2. When the new cell site is established, the aircore platform 200 tears down the previous link, thereby freeing up resources for other wireless customers.

In the scenario described above, the BSC 105_1 and 105_2 are both associated with the aircore platform 200 and certain hand off processing functions such as strength measurements are performed by the aircore platform 200. In a scenario involving a base transceiver station coupled to another mobile switching center, the base transceiver stations may perform these hand off processing functions.

As with other processing functions, the software architecture 300 of the aircore platform 200 is designed to use, as much as possible, generic processing for mobile unit hand offs. Thus, communications from the mobile units operating according to different protocols, e.g., GSM, TDMA, CDMA and AMPS are handled in a generic fashion, except where specific differences are required. The message flows associated with these protocols will be described later.

Referring to Figure 10, once a base station detects that the signal level has either dropped below the minimum, or exceeded the maximum, to continue the call on the current channel, hand off processing begins. Measurements are taken of bordering systems to determine the best candidate system, or target base station. The HOP 416 is involved in this for analog protocols and some inter-system hand offs. Otherwise, the step may be handled directly between the base station and the mobile unit. For digital protocols, the base station sends the target information to the HOP 416 for transmission to the CPM 414. For ISDN PRI + and DHD based analog protocols, the HOP 416 determines the appropriate target for the hand off. Next, the CPM 414 is

notified via the HOP 416 of the required hand off and begins establishing a voice circuit to the target system. Once confirmed, the CPM 414 sends the hand off command to the current serving base station. This information is passed to the mobile unit. The mobile unit confirms the reception of the target information and switches to the new frequence and voice path. Upon arrival at the new frequency, the new serving base station passes the confirmation to the CPM 414. The CPM 414 switches the voice path during this process to the new channel and tears down the voice path to the old serving system.

As noted above, the HOP 416 preprocess is limited. After the hand off is in progress, the HOP 416 is no longer involved. Call processing uses the information provided by the HOP 416 to establish appropriate resources to complete the hand off. Call processing is responsible for the control of the remaining portion of the hand off.

For ISDN PRI+ protocol hand offs, a message is sent to the aircore platform 200 from a base station to indicate that a mobile unit requires a hand off. The message specifies a protocol discriminator, a call reference (whose value is assigned in a SETUP message), a message type and a user identification. The aircore platform 200 in turn sends a hand off message request to the base station to request the base station measure a specific frequency. Finally, the base station sends a message to the aircore platform 200 to report the measured strength of the signal recorded on the base station.

ISDN PRI+ processing requires that the HOP 416 accept a hand off request from the DHI 503. Appropriate hand off related information, including call reference and RF channel, for example, is stored in the air core platform 200. The call reference is a number that is retrieved from the device handler thread data that is initially stored when call setup takes place. The RF channel is also retrieved from the device handler thread data. The air core platform 200 then sends measurement requests to appropriate boarder cells, sets a measurement request timer, and processes responses from the base station.

For DHD based protocol hand offs, the HOP 416 accepts a hand off request from one of the device handlers in the aircore platform 200. The appropriate hand off related information, including the call reference and RF channel, for example, are stored. The aircore platform 200 allocates a voice channel and sends measurement requests (SCANs) to the appropriate border cells, sets a measurement timer, and processes responses received from the base stations. For base stations not chosen for hand off, the aircore platform 200 initiates a channel release. If a suitable target cell is determined, the HOP 416 send the information to the CPM 414 for hand off.

For DHD based protocol hand off processing, a voice channel is assigned to each base station when the measurement process takes place. For example, if three base stations border the current wireless system and a measurement is to be taken, a voice channel is explicitly reserved in each base station. When the target base station is chosen, the voice channels in the other base stations must be released. To accomplish this release, the device handlers will allocate and release the appropriate channels for the measurements in accordance with commands sent by the HOP 416. If an allocation fails or there are no channels available in a base station, the device handlers send allocation failure events to the HOP 416, and the HOP 416 removes the base station from the candidate list for the current hand off.

IS-634 analog hand off processing requires the HOP 416 to send a measurement request to the AIM 430. The measurement request is then sent to appropriate border cells. The measurement requests are sent back to the requesting base station, and the information is forwarded to the HOP 416, for determination of the target cell.

The strength measurement message is transferred to cells that are listed in a Cell Identifier List parameter that is sent in the message. The HOP 416 stores the reference number against the requesting base station so the return messages find the correct base station. The reference number is timed in accordance with a base station timer for measurement collection. Responses received after timer expiration are discarded.

IS-634 TDMA hand off processing requires that the HOP 416 determine, based on information received from the base station in a hand off required message, the appropriate candidate cell. The HOP 416 then sends the appropriate information to the CPM 414. If the HOP 416 does not find a suitable target cell, the hand off is aborted.

IS-634 CDMA hand off processing requires the that HOP 416 determine an appropriate target cell, based on information received by the HOP 416 from the base station. The HOP 416 aborts the hand off if a suitable target cell is not determined.

GSM hand off processing requires that the HOP 416 use information received from the base station in the hand off required message to determine appropriate target cells. Once again, the HOP 416 aborts the hand off if a suitable target cell is not located.

For hand off processing from a multiple protocol base station, the message flows to the HOP 416 indicate the appropriate protocol of the mobile unit. For intersystem hand offs, messages related to the intersystem hand off preprocessing are sent from the HOP 416 to the IMH 432 and from the IMH 432. The border cell for measurement may be reached in the same manner as sending a message to multiple cell sites, except that the messages are intersystem. Therefore, the messages are sent to the IMH 432, or are received from the IMH 432 instead of the AIM 430 base station threads, DHI 503 or DHD 501.

Each cell supporting hand off in the aircore system 106 must have an associated list of border cells that are contacted in the event of a hand off attempt. These cells may have an identity that ties the cells to a link. These cells also have a protocol that the HOP 416 and the CPM 414 can use for determining message destination, supported protocols, and associated trunk groups, all of which may be used for new voice circuit allocations.

Because the aircore platform 200 is capable of processing a number of different protocol messages, some mechanism must be provided to determine the correct protocol. For messages received from a single-protocol BSS, the aircore

platform 200 determines the correct protocol by reference to the protocol established for that particular BSS. The BSS is then associated with a signaling link mechanism that connects the BSS to the MSC 210. The link may be a SS-7 base, TCP/IP, LAPD, CAS and ATM, for example. The MSC 210 associates the type of protocol supplied by the BSS to any incoming messages received from the BSS. The actual protocol for the base station is determined when the link to the BTS or BSS is brought into service. One example is when the DH-7 510 spawns a thread connecting the BSS to the MSC 210.

To ensure signaling messages used with the aircore platform 200 perform the same generic function across protocols, tables of messages may be used for different aircore platform functions. The table that follows shows some of the messages used for call processing in the aircore platform 200, and the accompanying messages according to specific protocols.

Internal AireCore Call Processing Event	GSM (Euro and US)	IS-634 CDMA	IS-634 TDMA	IS-634 AMPS
CPM_PAG_PAGE_MOBILE	Page Request	Page Request	Page Request	Page Request
PAG_CPM_PAGE_RESPONSE	Page Response	Page Response	Page Response	Page Response
MAKE_CALL	Setup	Setup	Setup	Setup
CALL_RECEIVED	Setup	Setup	Setup	Setup
ROUTE_CALL	Assignment Complete	Assignment Complete	Assignment Complete	Assignment Complete
ALERT_CALL	Alerting	Alerting	Alerting	Alerting
CALL_ALERTING	Alerting	Alerting	Alerting	Alerting
CONNECT_CALL	Connect	Connect	Connect	Connect
CALL_CONNECTED	Connect	Connect	Connect	Connect
CLEAR_CALL	Disconnect	Disconnect	Disconnect	Disconnect
CALL_DISCONNECTED	Disconnect	Release	Release	Release
CLEAR_CALL	Release	Release/Release Complete	Release/Release Complete	Release/Release Complete
CALL_CLEARED	Release Complete	Release Complete	Release Complete	Release Complete

Calls may fall into one of several scenarios, including mobile originated (a mobile unit originates the call), mobile terminated (a call to a mobile unit) and PSTN originated, for example. Mobile originated calls may be received at the MSC and may be originated at another wireless system (intersystem). Mobile originated calls may also be received at a BTS and may then be passed to the MSC.

The aircore platform 200 initiates a location update sequence to register a mobile unit with the aircore platform 200. A customer profile is retrieved from the VLR 422 or HLR 424 as necessary. Once a customer profile is retrieved, the procedures for call setup across the protocols is generic. The use of a standard internal set of procedures allows the call processing of the aircore platform 200 to be independent of the type of interface used when establishing the call. The events that are specific to a particular protocol are handled by individual components of the AIM 430. A CALL_RECEIVED message announces arrival of an incoming call to the CPM 414. When this message is sent, the customer profile is included as well as the selected traffic channel. The CALL_RECEIVED message is sent based on proper profile retrieval, authentication and channel selection. A ROUTE_CALL message is sent to the CPM 414 as an indication that the call may be routed to the network since the traffic channel allocation to the originating mobile unit was successful. The ROUTE_CALL message is sent based on proper channel assignment for the call. An ALERT_CALL event is received from the CPM 414 as an indication that the far end of the call is in the alerting state. When this event is received, an alert message is sent to the mobile unit. A CONNECT_CALL event is received as an indication that the far end has connected the call. This indication is passed on to the mobile station in the connect message. The above four events are used between the CPM 414 and all other subsystems for call originations in the system.

Mobile termination also uses a set of generic events and/or messages. However, mobile termination is more of a challenge than mobile origination, since the current operating mode of a subscriber is not known prior to querying the relative

databases. Similar to the mobile origination procedure and the location updating procedure, mobile termination is generic for all base station-type interfaces regardless of the protocol. The first query is to the HLR 424 via the IMH 432. Call processing sends an event to the IMH 432 requesting the current location of the customer and how to reach the customer. This request is sent without indication of the intrasystem protocol to use. The IMH 432 utilizes the MIN/MSISDN to HLR mapping table to determine a protocol and location of the HLR in the network.

For an internal HLR, the event is built and sent to the HLR 424 for processing. The protocol indicator is set based on the mapping table and a search is performed to locate the customer profile in the HLR database. If the customer profile is not found, the HLR 424 can optionally query the opposite side of the database in the case where the phone supports multiple modes and protocols. Once found, the VLR 422 is contacted (if not local) via standard procedures, such as ROUTE_REQUEST or PROVIDE_ROAMING_NUMBER.

For call tear down, the aircore platform 200 is based on the ISDN model for call release. This scenario is a three message sequence beginning with the requesting interface presenting notification of a disconnect. The notification is followed with a two event exchange with all involved subsystems for the call to command the release of the call and a return message to confirm the release. Low level processing in the aircore platform 200 ranges from changing the state of supervision bits to a two or three message exchange.

Figure 29a shows the basic components of the aircore platform 200 that are involved in call processing in the above scenarios. As shown in Figure 29a, calls to the aircore platform 200 may be received at a device handler such as the DH-7 510. The device handler DH-7 510 may communicate with the IMH 432 and the AMH 431. The VLR 422 and the HLR 424 and AC/AuC (not shown) may be addressed by the IMH 432 to retrieve customer-specific data and to perform other functions, including customer location, for example. The CPM 414 communicates with the ARS 434, the IMH 432 and the PAG 435.

The components shown in Figure 29a communicate via a set of generic messages. These messages indicate receipt of a call, authentication, call routing and call connection, for example.

To ensure proper tracking of a call and the call's processing, whenever a call comes into the aircore platform 200, the AMH 431 receives a notification from the DH-7 510. The AMH 431 accesses the decoder thread to decode the incoming message and to determine the appropriate action. If the message is the first message associated with a call, the AMH 431 allocates an area in the common memory 439, with an index to that area. For the duration of the call processing and the call, the designated area will be used as needed during the transaction processing. For example, the designated area includes the customer identification number and the base station identification.

The AMH 431 can spawn threads unique to base station protocols such as GSM or RDMA, TDMA, or AMPS. The AMH 431 may also spawn different threads depending on the manufacturer of a mobile unit.

The IMH 432 works in a fashion similar to that of the AMH 431 in that the IMH 432 spawns different threads, depending on the protocol required for the system (GSM or IS-41). When the IMH 432 deals with internal events, it shares the index and memory space used by the associated AMH 431. The IMH 432 pulls the message from the memory space of the common memory 439 created by the AMH 431, using the index created by the AMH 431.

The IMH 432 also processes events without the involvement of an AMH 431 thread. For these situations, the index and memory area are allocated by the IMH 432 thread. Memory and index allocation are coordinated within the AIM 430 subsystem.

The ARS 434 communicates with the VLR 422 via the IMH 432 thread to retrieve the requisite information to authenticate the subscriber and determine the validity of the transaction. The processing of the ARS 434 thread is made generic.

The PAG 435 thread tracks the outstanding page requests that are in process for the system. The PAG 435 thread receives incoming PAGE_MOBILE events from

the CPM 414 when a mobile unit is to be paged on the aircore system. The PAG 435 thread determines the appropriate base station resources that should be sent the PAGE message. The PAGE_REQUEST message is then communicated to the appropriate AMH 431 threads for processing. In a multi-protocol environment, the decision on the base stations that receive the PAGE_REQUEST event is based on the last known technology that the mobile unit was operating on. If a mobile unit has GSM and CDMA capabilities, and the last activity for the mobile unit was on the GSM portion of the system, the PAG 435 thread will process this as a GSM based paging. If however, there is not a last known technology for the mobile unit, all technologies within the mobile unit's capabilities are paged. If the mobile unit referenced above did not have a last known technology, both the CDMA and the GSM based paging would take place. Once the PAGE_RESPONSE message is received, the AMH 431 thread decodes the message and sends the decoded data, via the common memory 439 to the PAG 435 thread where an association is made between the incoming PAGE_RESPONSE and the previous outgoing PAGE_REQUEST messages. Based on the responding base station, the appropriate technology can be determined. The determination of the proper protocol at this point is much like the determination used for mobile originated actions. The responding base station determines the protocol based on its capabilities that were known when the interface to the base station was brought into service.

Call processing also uses a common reference scheme to track all events associated with a call. This scheme is illustrated in Figure 29b. Each call placed with the aircore platform 200 leads to creation of a session 490 with a session object header 491. The session object header 491 is created based on an index number generated from the board, span, and channel used for the first party involved in the call. Board, span and channel is a reference created relative to the physical interface used for system access. The session 490 adds and removes call objects 492_i as dictated by the progression of the call. Each session 490 has a reference number for the session that is based on the originator's board span and channel. However, the session may also

be indexed by an index number of the board, span and channel of any of the parties involved in the session. As shown in Figure 29b, each party object has its own data related to the customer or the interface to which it is related.

The authentication process may be initiated as a result of either a service request by a mobile unit or following the successful page of a mobile unit, but is performed primarily under the control of the VLR. The authentication process may be set up to be performed every time a mobile unit originates a call or when a call terminates at a mobile unit. Authentication may also take place whenever a location is updated for the mobile unit that is in a power on or an idle state. Finally, authentication may occur when a mobile unit registers by turning power on.

When a mobile unit originates a request for service, the mobile unit sends a message to the MSC, including the IMSI, a mobile identification number (MIN), or a temporary mobile subscriber identification (TMSI). The MSC may use the IMSI, the MIN, or the TMSI as the primary identification for the mobile unit. The IMSI is a permanent number that is assigned to every mobile unit. The MIN is a permanent number assigned to a mobile unit in the case where an IMSI is not used. (MIN is used in older AMPS based mobile units). The TMSI is assigned to a mobile unit only after an authentication, and has only local significance. If the TMSI is not recognized from the mobile unit, then a request is made to use the IMSI to continue the authentication. Upon successful authentication, a new TMSI (if used) is assigned to the mobile unit for future system access.

The authentication center is the source of data used in authentication. The authentication center does not store data for the customers. Instead, the authentication performs calculations using random numbers that are used in conjunction with data in the HLR to generate authentication data. When a customer first subscribes for service, the customer is assigned a secret key (K_i for GSM, A-key for CDMA, TDMA). The key and a random number supplied by the authentication are used by the authentication center to generate a result. The data calculations also yield values used for encryption keys. Depending on the protocol (GSM or IS-41 based), the

authentication process can occur at different times during the establishment of communications between the mobile unit and the MSC 210. The similarities between the authentication procedures are found in the fact that they produce results that are used for both access verification and encryption. Although the security calculations the responsibility of the authentication center, the initiation of the actual collection/transmission of data and the comparison to determine the validity of the access is the responsibility of the ARS 434 thread.

When authentication is requested, the MSC sends the random number of the mobile unit. The mobile unit retrieves the K_i from its initialization memory and calculates a signed response (SRES) and an encryption key K_c. The mobile unit then stores the K_c and sends the SRES to the MSC. The ARS 434 identifies that the SRES sent by the mobile unit matches the SRES calculated by the ARS 434. If the values match, the value of K_c stored in the mobile unit is assumed to be correct. This authentication process does not require that the encryption key K_c or the initial key K_i be transmitted over the air, thereby ensuring security for the encryption process.

An example of the GSM authentication process is described with reference to Figure 29c. The authentication process starts with step S10. The process then moves to step S12 where a mobile unit sends a service request message to the aircore platform 200. The message includes the temporary mobile subscriber identification (TMSI). The process them moves to step S14. In step S14, the ARS 434 compares the TMSI sent from the mobile unit to the TMSI recorded in the VLR 422. If the ARS 434 recognizes the TMSI, the process moves to step S20. Otherwise the process moves to step S16.

In step S16, the ARS 434 requests the IMSI for the mobile unit from the VLR 422. The process then proceeds to step S20. In step S20, the aircore platform 200 sends a message to the mobile unit indicating that the mobile unit is recognized. The process then moves to step S24.

In step S24, the mobile unit sends an authentication request message to the aircore platform 200. The process then moves to step S28. In step S28, the aircore

platform 200 sends a random number to the mobile unit and the authentication center platform 200 sends a random number to the mobile unit and the authentication center calculates a signed response (SRES) based on the random number. The process then moves to step S30.

In step S30, the mobile unit, after receiving the random number, retrieves the case K_i from its initialization memory and calculates the SRES and the encryption key K_c. The process then moves to step S34. In step S34, the mobile unit stores the encryption key K_c and sends the SRES to the aircore platform 200. The process then moves to step S38. In step S38, the ARS 434 compares the SRES calculated by the mobile unit with that calculated authentication center 200. If the two SRESs match, the process moves to step S44. Otherwise the process moves to step S40. In step S40, the aircore platform 200 sends a message to the mobile unit indicating that the authentication failed.

In step S44, the ARS 434 completes the authentication process. The process then moves to step S48. In step S48, the ARS 434 determines if the mobile unit needs a TMSI. If the mobile unit needs a TMSI, the process moves to step S50. In step S50, the ARS 434 assigns a TMSI to the mobile unit and stores the value of the TMSI in the VLR 422. The process then moves to step S60. In step S60, the authentication process ends and call processing continues. The message flows associated with a failed authentication are shown in Figure 58.

The above-described authentication process is the GSM authentication procedure, which is one of several authentication procedures available to the MSC. Other authentication processes may vary according to the call processing protocol, for example.

The operation of the aircore platform 200 in a multi-protocol wireless environment is explained below with reference to Figures 30-72.

When the aircore platform 200 and base station controllers are first brought on line, they exchange messages to ensure that all circuits are properly aligned. Figure 30 shows the reset and reset acknowledgment function when the base station controller is

started. In Figure 30 base station controller (BSC) 105 sends a reset message 620 to the device handler DH-7 510 to initiate the message sequence. The DH-7 510 transfers the message to the AMH 431 using DH-7_AMH_TRANSFER 621. The AMH 431 then sends an AMH_REC_RESET 622 to the REC 402 to initiate the reset. The REC 402 returns a reset acknowledge to the BSC 105 using the REC_AMH_RESET_ACK 623, which is sent to the AMH 431. The AMH 431 transfers the reset acknowledgment to the DH-7 510 using AMH_DH-7_TRANSFER 624. The DH-7 510 then sends a RESET_ACK 625 to the BSC 105. The BSC 105 then sends a BLOCKING or CIRCUIT_GROUP_BLOCK 626 to the DH-7 510. The DH-7 510 sends a DH-7_AMH_TRANSFER 627 to the AMH 431, which in turn sends an AHM_REC_ BLOCKING or AMH_REC_CIRCUIT_GROUP_BLOCKING 628 to the REC 402. This process then continues until all the circuits are in the appropriate state on the side of the aircore platform 200.

Figure 31 shows the reset and reset acknowledgment message flows for a base controller failure. The message flows are similar to those shown in Figure 30.

Figure 32 shows the message flows for the start up of the aircore platform 200. Upon startup, the REC 402 sends a REC_AMH_RESET 640 to the AMH 431. The AMH 431 transfers the reset message to the DH-7 510, using an AMH_DH7_ TRANSFER 641, and starts a T16 timer 644 using AMH_TMR_SET_TIMER (RESET) 643. The reset signal (RESET 642) is then sent to the BSC 105. The BSC 105 returns a RESET_ACK 645 to the aircore platform 200 and the AMH 431 releases the T16 timer 644 using AMH_TMR_RLS_TIMER (RESET) 647. The AMH 431 then passes the reset acknowledgment to the REC 402 using AMH_REC_RESET_ACK 648. Finally, the BSC 105 indicates blocking or circuit group blocking by sending an appropriate message to the aircore platform 200. This process continues until all the circuits are in the appropriate state on the side of the aircore platform 200.

Figure 33 shows the message flows for startup of the aircore platform 200 in the event of a circuit failure.

Figure 34 shows the message flows for startup of the aircore platform 200 in the event the T16 timer 644 times out before the BSC 105 returns a reset acknowledgment message to the aircore platform 200.

The aircore platform 200 may interface with other wireless systems. To set up a call, trunks are established between the two systems. Figures 35-40 are flow charts that show the message traffic used to establish and reset the trunks. Figure 35 shows the message flows when a far end system sends a blocking request to the aircore platform 200. A blocking 700 is received from the BSC 105 and transferred to the REC 402. The REC 402 returns a REC_AMH_BLOCKING_ACK 703 to the BSC 105. The state of the trunk circuit established could move to blocked or to blocked pending depending on whether a call is currently on the channel. The REC 402 assures the appropriate state changes occur.

Figure 36 shows the message flows for resetting a trunk circuit when no call is in progress. The BSC 105 sends a RESET_CIRCUIT 710 which is received at the REC 402. The REC 402 returns a REC_AMH_RESET_CIRCUIT_ACK 714 to the BSC 105 and the circuit is reset.

If a call existed on the trunk circuit, the message flows vary from that shown in Figure 36. Figure 37 shows the message flows in this situation. In Figure 37, the BSC 105 sends a RESET_CIRCUIT 720, which is transferred to the REC 402. The REC 402 sends a REC_CPM_CLEAR_CALL 723 to the CPM 414. The CPM 414 sends a CLEAR_CALL 724 to the AMH 431. The AMH 431 then clears the call. In parallel, the REC 402 sends a REC_AMH_RESET_CIRCUIT_ACK 725, which is transferred (726, 727) to the BSC 105.

The trunk circuit may also be reset by action taken by the aircore platform 200. Figure 38 shows the message flows in this situation. The REC 402 initiates a REC_AMH_RESET_CIRCUIT 730, which is transferred (736, 738) to the BSC 105. The AMH 431 sets the T12 timer 734 using an AMH_TMR_SET_TIMER (RESET_CIRCUIT) 733. The BSC 105 returns a reset circuit acknowledgment using RESET_CIRCUIT_ACK 735, which is transferred (736, 738) to the REC 402.

Because the REC 402 received the reset circuit acknowledgment before expiration of the T12 timer 734, the AMH 431 sends (737) a timer release message to the TMR 437 releasing the T12 timer 734.

In some cases, the BSC 105 will not return a reset circuit acknowledgment message before expiration of the T12 timer 734. Message flows in this situation are shown in Figure 39. When the T12 timer 734 times out, AMH 431 (747) sends a time out message to the REC 402. The REC 402 then repeats the reset circuit procedure n number of times, where n is a setable parameter. When the nth attempt to reset the trunk circuit fails, an alarm is raised at the Operations and Maintenance system. The far end state of the circuit remains in an unknown state.

Figure 40 shows the message flows associated with opening a trunk circuit. The message flows are similar to those in Figure 35.

The aircore platform 200 maintains the current location of mobile customers using the VLR 422 and HLR 424. When a mobile customer enters the region serviced by the aircore platform 200, the mobile customer's mobile unit 112 will register with the aircore platform 200. Figures 41 through 47 show the message flows associated with this registration process.

Figure 41 shows the message flows associated with the successful updating by location of a mobile unit 112. The flow assumes the mobile unit's profile has been previously retrieved and is stored in the VLR 422, and therefore no interaction is shown with the HLR 424. The BSC 105 sends (760) a location update request to the aircore platform 200. The request is received at the DH-7 510, which transfers (761) the update request.

At the ARS 434, the update request triggers authentication processing if the mobile unit 112 operates according to IS-41 protocols. The update request is then passed (763, 764) to the VLR 422. The VLR 422 updates the active file for the mobile unit 112 and returns a VLR registration notification response to the BSC 105. When the VLR registration notification response reaches the ARS 434, GSM authentication and ciphering are completed, if the mobile unit 112 operates according

to GSM protocols. The BSC 105 receives a LOCATION_UPDATING_ACCEPT 769 message from the DH-7 510. The DH-7 510 also provides a CLEAR_COMMAND 771 to the BSC 105. At this time, GSM TMSI reallocation occurs. The BSC 105 sends a CLEAR_COMPLETE 772 to the DH-7 510, which in turn sends a DH-7_ AMH_TRANSFER 773 to the AMH 431.

Figure 42 shows the message flows associated with location updating in the event the registration notification request is rejected. Figure 43 shows the message flows if the mobile unit 112 powers down while operating in the vicinity of the aircore platform 200.

Figure 44 shows the message flows associated with a periodic update in which the mobile unit 112 is already registered in the local VLR with the subscriber profile already having been retrieved from the HLR. The BSC 105 sends a LOCATION_ UPDATE_ REQUEST 1400, which is transferred (1401) to the AMH 431. The AMH 431 sends an AMH_ARS_LOCATION_UPDATING_REQUEST 1402 to the ARS 434. At this point, authentication may be performed (1404) for IS-41 protocol equipment. The ARS 1406 then sends an ARS_IMH_AUTHENTICATION_ REQUEST 1406 to the IMH 432. The IMH 432 then sends an IMH_VLR_ REGNOT_REQUEST 1408 to the VLR 422.

The mobile unit 112 was previously registered in the VLR 422. Therefore, the mobile unit's location is simply updated, and a VLR_IMH_REGNOT_RESPONSE 1410 is returned to the IMH 432. The IMH 432 sends an IMH_ARS_ AUTHENTICATION_RESPONSE 1412 to the ARS 434, which in turn sends (1414) and authentication result to the AMH 431. The AMH 431 then sends (1416) a LOCATION_UPDATING_ACCEPT 1418 to the BSC 105. The aircore platform 200 may also perform GSM authentication and ciphering (1413) and TMSI reallocation (1419).

The AMH 431 sends (1421) a CLEAR_COMMAND 1420 to the BSC 105. The BSC 105 returns a CLEAR_COMPLETE 1422 to the DH-7 510, which sends a DH7_AMH_TRANSFER 1423 to the AMH 431.

Figure 45 shows the message flows associated with location updating in which the mobile unit is not currently listed in the local VLR, but is listed in the local HLR. The initial message flows 1430 - 1438 are the same as shown in Figure 44 (1400 - 1408), including authentication (1434) for IS-43 protocol systems. However, the mobile unit 112 is not listed in the VLR 422. The VLR 422 returns a VLR_IMH_ REGNOT_ RESPONSE 1440 that indicates the mobile unit 112 is not registered in the VLR 422. In response, the IMH 432 sends an IMH_HLR_REGNOT_REQUEST 1442 to the HLR 424. The mobile unit 112 is registered in the HLR 424, and the HLR 424 returns an HLR_IMH_REGNOT_ RESPONSE 1444 to the IMH 432. The IMH 432 then sends an IMH_VLR_ REGNOT_RESPONSE 1446 to the VLR 422 to register the mobile unit 112 in the VLR 422. In response, the VLR 422 returns a VLR_IMH_REGNOT_ RESPONSE 1448 to the IMH 432 to indicate that the mobile unit 112 is registered in the VLR 422. The remaining message flows (1450 - 1464) are similar to those (1412 - 1422) shown in Figure 44.

Figure 46 shows the message flows when the IMH 432 determines that the mobile unit 112 is homed to an external HLR. The IMH 432 makes this determination based on an identification of the mobile unit 112 that is provided with the initial location update request messages. In Figure 46, the initial message flows (1480 - 1488) are similar to those shown in Figure 44. The VLR 422 notifies the IMH 432 that the mobile unit 112 is not registered in the VLR 422. Based on the identification of the mobile unit 112, the IMH 432 then determines that the mobile unit 112 is registered in an external HLR. The identification is used to locate the external HLR. The IMH 432 sends a MAP_UPDATE_LOCATION_INVOKE (GSM) or a REGISTRATION_ NOTIFICATION_INVOKE (IS-41) 1492, 1493 to the external HLR. The IMH 432 also sets a REGNOT timer 1496. The external HLR returns (1494) a MAP_UPDATE_LOCATION_RESULT (GSM) or a REGISTRATION_NOTIFICATION_RETURN _RESULTS (IS-41) 1495 to the MSC 210. The IMH 432 releases the REGNOT timer 1496 and sends an IMH_VLR_ REGNOT_RESPONSE 1498 to the VLR 422, causing the mobile unit 112 to be

registered in the VLR 422. The VLR 422 then returns a VLR_IMH_REGNOT_RESPONSE 1499 to the IMH 432. The remaining message flows (1500 - 1509) are similar to those shown in Figure 44.

Figure 47 shows the message flows when the IMH 432 determines that the mobile unit 112 is homed to an external HLR, but the REGNOT timer 1496 times out before the external HLR returns a response. The IMH 432 makes this determination based on an identification of the mobile unit 112 that is provided with the initial location update request messages. In Figure 47, the initial message flows (1510 - 1524) are similar to those shown in Figure 46. When the REGNOT timer 1496 times out, the TMR 437 sends a TMR_IMH_TIMER(REGNOT) 1525 to the IMH 432. The channel is cleared (1526 - 1535) in a manner similar to that in Figure 47.

Figures 48-71 show the message flows associated with call processing. Figure 48 is a flow chart for a mobile originated call. The mobile originated call begins when the BSC 105 receives an indication from the mobile unit 112 that the mobile unit 112 will originate a call. The BSC 105 may receive the number of the called party that was dialed at the mobile unit 112.

The BSC 105 transmits a CM_SERVICE_REQUEST 800 to the aircore platform 200 where the message is received and processed by the DH-7 510. The DH-7 510 establishes the SS-7 link and ensures proper message routing for the inbound message. The DH-7 510 sends a DH-7_AMH_TRANSFER 801 to the appropriate AMH 431 (either the GSM or the IS 634 thread). The AMH 431 sends an AMH_ARS_CM_SERVICE_REQUEST 802 to the ARS 434.

The ARS 434 provides the appropriate calculations and processing to authenticate the given base station interface. The ARS 434 then sends an ARS_IMH_AUTHENTICATION_REQUEST 803 to the appropriate IMH 432. The IMH 432 sends an IMH_VLR_REGNOT_REQUEST 804 to the VLR 422 to notify the VLR 422 of the incoming call. The VLR 422 registers the mobile unit 112 as an active unit and then sends a VLR_IMH_REGNOT_RESPONSE 805 to the appropriate IMH 432. The IMH 432 sends an IMH_ARS_AUTHENTICATION_RESPONSE 806

to the ARS 434. If the mobile unit 112 uses a GSM protocol, GSM authentication and ciphering are completed at this point.

The ARS 434 sends an ARS_AMH_AUTHENTICATION_RESULT 807 to the AMH 431 and the appropriate AMH 431 sends an AMH_DH-7_TRANSFER 808 to the DH-7 510. The DH-7 510 sends a CM_SERVICE_ACCEPT 809 to the BSC 105 indicating to the BSC 105 that the mobile unit 112 is allowed to proceed with the call processing using the aircore platform 200.

During the above-described processing for a GSM protocol mobile unit, the ARS assigns the call a temporary mobile subscriber identity (TMSI). The TMSI is calculated based on an index in the VLR 422, the time of day, and the identity (IMSI) of the mobile unit 112. The TMSI provides additional security so that if the mobile call is tapped, the identity of the calling mobile party cannot be determined.

In Figure 48, the mobile call process then proceeds to the call setup stage and the BSC 105 transmits a SETUP 810 to the DH-7 510. The SETUP 810 includes the call number and an identity of the mobile customer. The DH-7 510 transfers the information to the appropriate AMH 431 by sending a DH-7_AMH_TRANSFER 811. The AMH 431 then notifies the CPM 414 that a mobile originated call has been received by sending a CALL_RECEIVED 812. When the CPM 414 is notified that the mobile call has been received, the CPM 414 allocates a voice channel for a mobile call to carry the voice between the aircore platform 200 and the BSC 105. The mobile call is assigned a session number and each party of the mobile call is assigned an object of the mobile call.

The AMH 431, the DH-7 510 and the BSC 105 communicate through a series of messages 813-821 that the call assignment request has been made and completed. During this processing, a T10 timer 818 is used to time out the call in the event a voice channel cannot be readily assigned. Once the channel assignment is complete and the radio and voice channels are assigned, the AMH 431 sends a ROUTE_CALL 822 to the CPM 414, informing the CPM 414 to proceed with the call because all of the incoming wireless communication requirements have been established. The CPM

414 determines, based on the number that is to be dialed out, what facility the call should go to and in what format. The CPM 414 sends a MAKE_CALL 823 to the appropriate device handler (DHD 501, DHI 503 or DH-7 510) for a land-based or wired call. If the number to be dialed is for a mobile unit, the CPM 414 sends a location request (not shown) through the IMH 432 to the HLR 424 to find out where the called mobile customer is.

As shown in Figure 48, the device handler returns a CALL_ALERTING 824 to the CPM 414 indicating an attempt to connect to the called party. The alerting message is then passed to the BSC 105 using an ALERT_CALL 825, AMH_DH-7_TRANSFER 826 and an ALERTING 827.

After the MAKE_CALL 823 is transmitted, the called party should return a signal to the appropriate device handler, which then sends a CALL_CONNECTED 828 to the CPM 414. The CPM 414 sends a CONNECT_CALL 829 to the AMH 431, which propagates as a CONNECT 831 to the BSC 105. At the same time, the AMH 431 sets a T313 timer 833 using a AMH_TMR_SET_TIMER (CONNECT) 832 to the TMR 437. The TMR 437 then waits for a connection acknowledgment that indicates the called party and the calling party are connected. In particular, the BSC 105 sends a CONNECT_ACK 834 to the DH-7 510, and the connect acknowledgment is propagated (835) to the AMH 431. The AMH 431 then releases the T313 timer 833 by sending an AMH_TMR_RECS_TIMER (CONNECT) 836 to the TMR 437. At this point, the mobile originated call is connected.

Figure 49 shows call processing for normal mobile termination. The aircore platform 200 receives a call at a device handler 501 or 503. The device handler sends a CALL_RECEIVED 840 to the CPM 414. The CPM 414 forwards a CPM_IMH LOCATE_SUBSCRIBER 841 to the IMH 432 initiating a subscriber location action (not shown) in which the HLR 424 (not shown) is queried to determine the location of the called mobile unit 112. The IMH 432 returns an IMN_CPM_SUBSCRIBER_LOCATION 842 to the CPM 414 indicating the location of the mobile 112 unit within the wireless area served by the aircore platform 200. The CPM 414 then initiates a

CPM_PAG_PAGE_MOBILE 843 to the PAG 435 to page the called mobile unit 112. The called mobile unit 112 is then paged (845, 846) and returns a response (850-852). At the same time, the AMH 431 initiates a timer 855 that will timeout the page request if a page response from the mobile unit 112 is not received within a set time period.

As shown in Figure 49, once the page response is received, the ARS 434 initiates an ARS_IMH_ AUTHENTICATION_REQUEST 853 to the IMH 432. The IMH 432 sends an IMH_VLR_REGNOT_REQUEST 854 to the VLR 422 to retrieve the profile information from the VLR 422 for the mobile unit 112. The VLR 422 returns a VLR_IMH_REGNOT_ RESPONSE 857 containing the requested data for the mobile unit 112 in the VLR 422.

During the time period that the mobile unit 112 is being paged and the authentication and registration notification messages are being passed, authentication and ciphering, may occur. In particular, for IS-41 protocol systems, authentication may occur at block 848. For GSM protocol systems, GSM authentication, ciphering and TSMI reallocation may occur at block 859.

As shown in Figure 49, when the AMH 431 receives the authentication result, the AMH 431 initiates an AMH_PAG_PAGE_RESPONSE 861 which is passed (862) to the CPM 414. The CPM 414 then initiates a MAKE_CALL 863. The aircore platform 200 then proceeds to call setup, channel assignment, alerting, call connection and call connection acknowledgment (864-889).

Figure 50 shows a mobile terminated call in which no response is received to the PAGE_MOBILE message, and the page timer times out. In Figure 50, the messages 900-906 are similar to messages 840-846 of Figure 49. An AMH_TMR_SET_TIMER (PAGE_RESPONSE) 907 is sent by the AMH 431 to the TMR 437. When the AMH 431 fails to receive a response to the page request, the timer 908 times out in the TMR 437, and the TMR 437 sends a TMR_AMH_TIMER (PAGE_RESPONSE) 910 to the AMH 431. The AMH 431 then initiates a series of messages 911 to 916 to update the VLR 422. The CPM 414 receives a PAGE_CPM_

PAGE_RESPONSE 918 indicating no response to the mobile page, and as a result the CPM 414 does not issue a MAKE_CALL message.

Figure 51 shows the message flows associated with a PSTN initiated disconnect. The device handler (DHD 501 or DHI 503) receives a disconnect signal from a telephone or other device connected to the PSTN. The device handler sends a DISCONNECT_CALL 930 to the CPM 414, which returns a CLEAR_CALL 932 to the device handler and issues the CLEAR_CALL to the AMH 932. As a result, a DISCONNECT (GSM) or RELEASE (IS-634) 934 is sent to the BSC 105, which returns a RELEASE (GSM) or RELEASE_COMPLETE (IS-634) 938. A T305 or T306 (GSM) or T308 (IS-634) timer 936 is also set in the TMR 437, and if the RELEASE or RELEASE_COMPLETE 938 is not received before expiration of the timer 936, the channel is released.

Once the RELEASE or RELEASE_COMPLETE 938 is received, the AMH 431 sends a CALL_CLEARED 944 to the CPM 414, and a RELEASE_COMPLETE 943 is sent to the BSC 105. The DH-7 510 then sends a CLEAR_COMMAND 946 to the BSC 105, and an internal timer 948 is set in the TMR 437. The BSC 105 returns a CLEAR_COMPLETE 949, and the internal timer 948 is released.

Figure 52 shows a mobile originated disconnect. A DISCONNECT (GSM) or RELEASE (IS-634) 960 is received at the DH-7 510 from the BSC 105. The DH-7 510 transfers the message to the AMH 431, which initiates a DISCONNECT_CALL 962 to the CPM 414. The CPM 414 initiates a CLEAR_CALL 964 to the AMH 431 and the device handler 501 or 503. The AMH 431 transfers (965) the CLEAR_CALL 964 command to the DH-7 510, which initiates a release (GSM) or RELEASE_COMPLETE (IS-634) 966. The device handler 501 or 503 sends a CALL_CLEARED 967 to the CPM 414. The AMH 431 also initiates a T308 timer 964 (GSM) to clear the channel in case a RELEASE_COMPLETE message is not received from the mobile unit 112 within the time period set by the T308 timer 964. The BSC 105 returns a RELEASE_COMPLETE (GSM) 970 to indicate that the mobile unit 112 has completed disconnect, and the AMH 431 releases the T308 timer 964 and sends a

CALL_CLEARED 975 to the CPM 414. The AMH 431 sends an AMH_DH-7_TRANSFER 967 to the DH-7 510, which initiates a CLEAR_COMMAND 977 to the BSC 105. The AMH 431 also sets an internal timer 980 to clear the channel in the event that a CLEAR_COMPLETE message is not received from the BSC 105. The BSC 105 then initiates a CLEAR_COMPLETE 978 and the AMH 431 releases (981) the internal timer 980.

Occasionally, a base station may not return a response to the MSC 210 within the timeout specified. The message flows for this situation is shown in Figure 53. The message flow begins after the service request message flows shown in Figure 48 (messages 800 - 809) are completed. A SETUP 960 is sent from the BSC 105 and in response, the AMH 431 sends a CALL_RECEIVED 991 to the CPM 414 and sets the T10 timer 818. Because the BSC 105 does not return a response to the ASSIGNMENT_ REQUEST 996, the T10 timer 818 times out and the AMH 431 sends a DISCONNECT_CALL 1000 to the CPM 414 to initiate a clear call sequence. The CPM 414 sends a CLEAR_CALL 1001 to the AMH 431, which is passed (1002) to the BSC 105 as a DISCONNECT (GSM) or RELEASE (IS-634) 1003. The AMH 431 also sets (999) a channel release timer 936 in order to release the channel if the BSC 105 does not respond to the DISCONNECT 1003.

The BSC 105 then sends a RELEASE (GSM) or RELEASE_COMPLETE (IS-634) 1004, which is transferred (1005) to the AMH 431. The AMH 431 releases (1006) the timer 936, sends a CALL_CLEARED 1007 to the CPM 414, and sends (1008) a RELEASE_COMPLETE 1009 (GSM) to the BSC 105. The AMH 431 then sends (1010) a CLEAR_COMMAND 1011 to the BSC 105 and sets (1012) an internal timer 1013. The BSC 105 returns a CLEAR_COMPLETE 1014, which is transferred (1015) to the AMH 431, which then releases (1016) the internal timer 1013.

Figure 54 shows the sequence of a time out of the T10 timer 818 for a mobile terminated call. The initial message flows are the same as messages 840 - 860 shown in Figure 49 and are not repeated in Figure 54. The AMH 431 sends a

AMH_PAG_PAGE_ RESPONSE 1020 to the PAG 435, which is passed (1021) to the CPM 414. The CPM 414 sends a MAKE_CALL 1022, which is passed as a SETUP 1025 to the BSC 105. The BSC 105 returns a CALL_CONFIRMED 1027. The T303 timer 869 is set (1026) and released (1028, 1029). The BSC 105 receives an ASSIGNMENT_REQUEST 1031, and the AMH 431 sends an AMH_TMR_SET_TIMER (ASSIGNMENT_REQUEST) 1032 to set the T10 timer 818. However, the BSC 105 does not send a response to the ASSIGNMENT_REQUEST 1031, and the T10 timer 818 times out. As a result, the AMH 414 sends a DISCONNECT_CALL 1036 to initiate tear down of the channel. The CPM 414 then sends a CLEAR_CALL 1037, and the channel teardown proceeds through several message sequences to release the channel and to report that the call is cleared (1038 - 1054) in the same manner as shown in Figure 53. Coincident with the CLEAR_CALL 1037, the CPM 414 may send the calling party an announcement to inform the calling party that the call cannot be completed to the mobile unit 112.

Figure 55 shows the message flows associated with a mobile originated call when the channel assignment fails. Channel assignment failure can occur for a variety of reasons including when the BSC 105 and the MSC 210 do not agree on the state of the channel, for example. The BSC 105 and the MSC 210 will not agree on the state of the channel if the BSC 105 indicates the channel is blocked and the MSC 210 indicates the channel is unblocked, for example. The BSC 105 also may incur a failure in the establishment of the radio portion of the connection.

In Figure 55, a service request is initiated using the same message sequence (800 - 809) as shown in Figure 48. The BSC 105 then sends a SETUP 1060, which is received at the DH-7 510. The message is transferred (1061) to the AMH 431, which sends a CALL_RECEIVED 1062 to the CPM 414. The call proceeds through call setup (1063 - 1065) until an ASSIGNMENT_REQUEST 1066 is sent to the BSC 105. In this case, however, the BSC 105 returns an ASSIGNMENT_FAILURE 1070. As a result, the MSC 210 proceeds with call tear down (1071 - 1090) in the same manner as shown in Figure 53 (1002-1016).

Figure 56 shows the message flow associated with a mobile terminated call when the channel assignment fails. In Figure 56, the initial messages (840 - 860) shown in Figure 49 have already been completed. The AMH 431 then sends an AMH_PAG_PAGE_RESPONSE 1095 to the PAG 435, which passes the message (1096) to the CPM 414. The call setup phase begins with a MAKE_CALL 1097, a SETUP 1101, a CALL_CONFIRMED 1103 and an ASSIGNMENT_REQUEST 1107.

The BSC 105 returns an ASSIGNMENT_FAILURE 1109, indicating, for example, that the BSC 105 and the MSC 210 do not agree as to the state of the channel allocated between the BTS and the MSC 210. The AMH 431 sends a DISCONNECT_CALL 1112 to the CPM 414, which returns a CLEAR_CALL 1115. Call tear down then proceeds in the same manner as shown in Figure 53.

Figure 57 shows the message flows associated with a call disconnect when the CLEAR_COMMAND internal timer times out. For the PSTN initiated disconnect and the mobile originated disconnect, the message flows are the same once the CALL_CLEARED 1135 is sent by the AMH 431 to the CPM 414. The AMH 431 sends (1136) a CLEAR_COMMAND 1139 to the BSC 105 and sets (1137) a CLEAR_COMMAND internal timer 1138. The BSC 105 does not respond with a CLEAR_COMPLETE message, and the internal timer 1138 times out (1140) releasing the channel.

Figure 58 shows the message flows when the MSC 210 rejects a CM service request. The BSC 105 sends a CM_SERVICE_REQUEST 1145 to the MSC 210. The DH-7 510 determines the protocol of the sending mobile unit 112 and spawns an appropriate thread and forwards (1146) the CM_SERVICE_REQUEST 1145 to the AMH 431. The AMH 431 sends an AMH_ARS_CM_SERVICE_REQUEST 1147 to the ARS 434, which forwards an ARS_IMH_AUTHENTICATION_REQUEST 1148 to the IMH 432. The ARS in turn sends a registration notification (IMH_VLR_ REGNOT_REQUEST 1149) to the VLR 422. The VLR 422 returns a response (1150) that rejects the service request. This response is passed (1151) to the ARS

434, which sends a CM_SERVICE_REQUEST 1152 to the AMH 431. The AMH 431 transfers (1153) the rejection to the BSC 105 as a CM_SERVICE_REJECT 1154.

Figure 59 shows the message flows associated with a mobile terminated call in which the CPM 414 times out waiting for an alerting message from the AMH 431. The initial message flows are the same as shown in Figure 49 (i.e., 840 - 860). The AMH 431 sends (1155) a page response to the PAG 435, which forwards (1156) the page response to the CPM 414. The CPM 414 sends a MAKE_CALL 1157 to the AMH 431, which transfers (1158) the message as a SETUP 1159 to the BSC 105. The CPM 414 also sets the T310 timer 876, waiting on receipt of an alerting message. The BSC 105 returns a CALL_CONFIRMED 1165, which is passed (1166) to the AMH 431. A channel assignment is then completed (1168 - 1172). However, the BSC 105 does not send an alerting message to the MSC 210, and the T310 timer 876 times out in the CPM 414. As a result, the CPM 414 sends a CLEAR_CALL 1173 to the AMH 431, which is passed (1174) to the BSC 105 as a DISCONNECT (GSM) or a RELEASE (IS-634) 1175. The call tear down then proceeds (1210-1226) in the same manner as shown in Figure 53 (1002 - 1016).

Figure 60 shows the message flows associated with a mobile terminated call in which the call confirmed timer times out in the TMR 437. The initial message flows are the same as those shown in Figure 49 (840 - 860). The AMH 431 sends an AMH_PAG_PAGE_RESPONSE 1200 to the PAG 435, which forwards (1201) it to the CPM 414. The CPM 414 sends a MAKE_CALL 1203 to the AMH 431 and sets the T310 timer 876. The AMH 431 transfers (1204) the MAKE_CALL 1203 to the BSC 105 as a SETUP 1205 and sets (1206) the T303 call confirmed timer 869 in the TMR 437. However, the BSC 105 does not return a call confirmed message to the MSC 210, and the T303 timer 869 times out (1207). The AMH 431 sends a DISCONNECT_CALL 1208 to the CPM 414 and the CPM 414 responds with a CLEAR_CALL 1209. The call tear down then proceeds (1210-1226) in the same manner as shown in Figure 53 (1002 - 1016).

Figure 61 shows the message flows associated with a mobile terminated call in which the call connect timer times in the CPM 414. The initial message flows are the same as those shown in Figure 49 (840 - 860). The AMH 431 sends an AMH_PAG_PAGE_RESPONSE 1230 to the PAG 435 and call set up proceeds through make call, call confirmed and channel assignment (1231 - 1245). The BSC 105 then sends an ALERTING 1246, which is transferred (1247) to the AMH 431. The AMH 431 sets (1248) a T301 call connected timer 883 in the CPM 414. However, the BSC 105 does not return a connect message, and the T301 timer 883 times out. The CPM 414 sends a CLEAR_CALL 1250 to the AMH 431, and call tear down proceeds in the same manner as shown in Figure 53 (1002 - 1016).

Figure 62 shows the message flows associated with a mobile originated call in which the BSC 105 does not send a connect acknowledge message to the MSC 210 and the T313 connect acknowledge timer 833 times out. The initial message flows are the same as shown in Figure 48 (800 - 809). The call proceeds through setup, channel assignment, alerting and call connection (1270 - 1294). The AMH 431 sets (1293) the T313 connect acknowledge timer 833. However, the BSC 105 does not return a connect acknowledgment, and the T313 timer 833 times out (1297). The MSC 210 then proceeds through call tear down.

Figure 63 applies to GSM and IS-634. Figure 63 shows the message flows associated with a call disconnect (mobile or PSTN originated) in which the T308 (GSM) release complete timer 964 times out. Similar message flows would exist for IS-634 protocol equipment. The initial message flows are the same as shown in Figure 51 or Figure 52. The CPM 414 sends a CLEAR_CALL 1300 to the AMH 431, which is transferred (1301, 1302) to the BSC 105. The AMH 431 also sets (1303) a T308 release complete timer 964. As shown in Figure 63, the BSC 105 does not return a release complete message and the T308 timer 964 times out (1304). The AMH 431 then sends (1305) a second RELEASE 1306 to the BSC 105 and sets (1307) a second T308 timer 964'. The BSC 105 returns a RELEASE_COMPLETE 1308, and the AMH 431 releases (1310) the T308 timer 964'. If the T308 timer 964'

were to expire, the AMH 431 could release the transaction and send a call cleared message to the CPM 414. The MSC 210 may then go through a call clear sequence. Returning to Figure 63, the AMH 431 next sends a CALL_CLEARED 1315 to the CPM 414, sends (1316) a CLEAR_COMMAND 1317 to the BSC 105, and sets (1318) a clear command internal timer 1319. The BSC 105 returns a CLEAR_COMPLETE 1320 to the MSC 210. The AMH 431 then releases the internal timer 1319.

Figures 64 - 66 show the message flows associated with processing a dual tone multiple frequency (DTMF) signal. As shown in Figures 64 - 66, the BSC 105 initiates the processing by sending a START_DTMF (1330 in Figure 64) and the CPM 414 returns a CPM_AMH_START_DTMF_ACK (1333 in Figure 64).

Figures 67-71 are flow charts showing message handling associated with call processing with an HLR (internal or external).

Figure 67 shows the message flows when an incoming call is received at the MSC 210, a location request is sent to the HLR 424, and the HLR 424 indicates that the mobile unit 112 is operating locally. The DHI 501 sends a CALL_RECEIVED 1536 to the CPM 414. The CPM 414 sends a CPM_IMH_LOCATE_SUBSCRIBER 1537 to the IMH 432. The IMH 432 then sends an IMH_HLR_LOCATION_ REQUEST 1538 to the HLR 424. The HLR 424 returns a response (1539) indicating that the mobile unit 112 is homed on the local system and is operating locally. The IMH 432 then provides an IMH_CPM_SUBSCRIBER_LOCATION 1540 to the CPM 414 indicating that the mobile unit 112 is operating locally. The remaining message flows 1541 - 1595 are similar to those shown in Figure 49.

Figure 68 shows the message flows associated with an incoming call to a mobile unit 112 that is operating locally but is homed on an external HLR. The DHI 503 sends a CALL_RECEIVED 1600 to the CPM 414, which sends a CPM_IMH_ LOCATE_SUBSCRIBER 1602 to the IMH 432. Because the mobile unit 112 is not homed locally, the IMH 432 sends a location request 1600/1608 to the external HLR and sets (1604) a LOCREQ timer 1605. The IMH 432 then receives a return

1610/1612 from the external HLR and releases (1614) the LOCREQ timer 1605. Then the IMH 432 sends an IMH_CPM_SUBSCRIBER_LOCATION 1616 to the CPM 414 indicating the location of the mobile unit's 112 HLR. The remaining message flows 1620 - 1699 are similar to those in Figure 49.

Figure 69 shows the message flows associated with call processing for a mobile termination in which the mobile unit 112 is homed on the HLR 424 but is operating externally to the wireless network controlled by the aircore platform 200. In this case, the mobile unit 112 will be registered on an external VLR. The CPM 414 receives a CALL_RECEIVED 1700 and sends a location request 1702 to the IMH 432. The IMH 432 sends a location request 1704 to the HLR 424. Because the mobile unit 112 is registered on another wireless network, the HLR 424 sends a route request 1706 to the IMH 432, which sends an invoke 1710 to the external VLR and sets a ROUTEREQ timer 1709. The external VLR returns the results 1712 to the IMH 432, and the IMH 432 releases the ROUTEREQ timer 1709. The IMH 432 also sends an IMH_HLR_ROUTE_REQUEST_RESPONSE 1716 to the HLR 424 and the HLR 424 returns a location response 1718. The IMH 432 then sends (1720) the location of the mobile unit 112 to the CPM 414, which issues a MAKE_CALL 1722 to the roaming number provided by the external wireless network serving the mobile unit 112. The process then proceeds through call alerting and call connection.

Figure 70 shows the message flows for call processing for a mobile terminated call when the mobile unit 112 is homed on an external HLR and is operating externally to the wireless network controlled by the aircore platform 200. The CPM 414 receives a CALL_REQUESTED 1730 from the DHD 501. The CPM 414 then sends a CPM_IMH_LOCATE_SUBSCRIBER 1732 to the IMH 432. The IMH 432 sets a timer 1734 and sends an invoke message 1736 to the DH-7 510. The DH-7 510 sends 1736 the invoke message to the external HLR and receives (1738) a response. The DH-7 510 then sends a results message 1739 to the IMH 432. The remaining message flows are similar to those shown in Figure 69.

Figure 71 shows the message flows associated with call processing for a mobile unit 112 homed on an external HLR but operating within the wireless network controlled by the aircore platform 200. In this scenario, the mobile unit 112 receives a call that goes initially to the MSC of the external wireless network. The call is then routed to the wireless network controlled by the aircore platform 200. The MSC 210 receives an invoke message 1751 from the external HLR. The IMH 432 then sends a route request 1752 to the VLR 422. Because the mobile unit 112 is roaming, it will be registered on the VLR 422. The VLR 422 returns a route request response 1753 to the IMH 432, which sends a roaming number 1754 to the external HLR indicating the location of the HLR 424. The remaining message flows are similar to those in Figure 49 with the exception that the IMH 432 does not have to locate the mobile unit.

Figure 72 shows the message flows associated with hand off pre-processing for an ISDN PRI+ protocol. The BSC 105 sends a HANDOFF_REQUEST 1850 to the DHI 503, which sends a HANDOFF_REQUEST 1852 to the HOP 416. The HOP 416 returns a MEASUREMENT_REQUEST 1854 to the DHI 503, which sends a HANDOFF_MEASUREMENT_REQUEST 1856 to the BSC 105. The HOP 416 also sends measurement requests (1854'/1856') to all base stations capable of handling the message traffic from the mobile unit for which the hand off is requested. The BSC 105 returns a HANDOFF_MEASUREMENT_RESPONSE 1858 to the MSC 210, and a MEASUREMENT_RESPONSE 1860 is sent to the HOP 416. Other base stations likewise return measurement responses (1858', 1860') to the MSC 210. The HOP 416 then proceeds with the handoff process. Figure 72 shows the initial message responses for the ISDN PRI+ protocol. Other protocols use similar initial measurement flows to establish a target base station for hand off.

Wireless customers can pay for their services in a variety of ways including an annual subscription and on a monthly basis, for example. In both these cases, the customer pays for the call actually made (air time) plus a periodic base fee. Customers can also pay for wireless services in advance through a prepaid system. Figure 73 is a logical diagram of an aircore prepaid rating system 2100. The aircore

prepaid rating system 2100 includes a data management module 2101, a rating administration module 2102, a distributor data module 2103, and distributor rate plans 2110 through 2119. Thus, a distributor can have up to ten different rate plans. Each customer can select one of the ten different rate plans for each distributor in the aircore prepaid rating system 2100.

The distributor can be viewed much like a class of service is viewed in routing. The distributor is a classification of rating service that is assigned to certain groups of subscribers in the aircore system. A distributor could be a point of sale, a corporate customer, or an operator classification for a group of customers. Within each distributor, there can be up to ten different rate plans configured. A rate plan establishes the air time rates for the plan. The combination of distributor and rate plan provide a comprehensive rating schedule for a variety of combinations within the system.

Within each customer profile 460 (see Figure 20) in the aircore HLR 424, the parameter for prepaid service is configured as prepaid or not. The prepaid configuration of the customer is controlled via a prepaid check box and associated prepaid window and a graphical user interface (see Figure 89). The window is used to define the distributor and rate plan that the customer uses for the prepaid service. Also, the credited amount for the account is input with the prepaid data. This field tracks the amount of service that a customer is allowed on the system. The amount is updated in real-time to track the usage of the system by the customer.

A third part of the prepaid system is bill generation that is integrated as part of a call record management subsystem. The set of functions available allows the operator the ability to create a range of reports based on operator defined billing cycles.

In operation, when a customer who has elected a prepaid plan uses the aircore prepaid rating system 2100, the customer profile 460 is pulled from the HLR 424 to determine the applicable distributor rate plan. The information from the customer profile 460 is passed to the CPM 414. The CPM 414 determines if the customer has

an account balance sufficient to pay for the call. The CPM 414 also determines the least cost route for the call, including defining the land charge and the air time charge associated with the destination and time of day of the call to come up with the per minute charge. This value is then used to set a timer that will indicate when the customer's account reaches a balance that corresponds to two minutes left on a call.

Once the prepaid call has begun, the timer begins a time out process and when the two minute position is reached, a tone warning is provided to the customer indicating that the customer is running out of money. No further warnings are provided, and once the next two minutes have expired, the TMR 437 sends a message to the CPM 414 indicating that the time has expired. The CPM 414 then initiates a call cutoff, terminating the prepaid call. In this way, the customer cannot overrun the prepaid account balance

At the completion of the call, the billing system 260 calculates how much the call actually cost for the customer and updates the amount in the HLR 424. A call detail record (CDR) is prepared that provides the detailed information regarding the call so that the billing system 260 can determine the remaining account balance. The bill generated by the billing system 260 is then used to update the customer profile 460.

In the wireless environment shown in Figure 1a-1d, there may be a need to locate customers who place distress, or emergency (911), calls. These 911 calls are used to gain rapid access to local authorities and emergency service centers. if a customer places a 911 call from a wired device, locating that customer is easy using call tracing procedures. Customers using wireless devices are more difficult to locate.

The air core platform 200 solves the problem of wireless customer location by creating an identification number based on the current position of the customer in the wireless environment. The aircore platform 200 uses the identification number as the dialed number to route the call to an emergency service center. The identification number includes the position data available from the BSS where the call origination is received. The location information received from the BSS is coded in hexadecimal.

The aircore platform 200 converts the hexadecimal number to binary coded decimal (BCD) and uses this number as an indication of the customer's location.

Following is an example of the data conversion used by the aircore platform 200 to convert the location data received from the BSS 110 to a dialed number for emergency callers. The data received could be as shown in the following table in which the BSS 110 receives the location of a customer with cell ID granularity. The MSC 210 converts the data as shown in the table.

FIELD	RESULTING NUMBER OF DIGITS
Mobile Country Code	Up to 3
Mobile Network Code	Up to 3
Location Area ID	Up to 3
Cell ID	Up to 3

The numbers produced from the conversion yields a unique 12 digit number identifying that cell in the system.

The aircore platform 200 may incorporate the concept of customer groups to define the routing translations (classes of service) for the wireless network. A customer group is a table of number ranges that is used to determine if a call is allowable. The aircore platform 200 searches the list of entries in the table. If a match is found, the call is allowed to proceed. If a match is not found, the call is not allowed to proceed in the wireless network.

The aircore platform 200 allows for the definition of up to 256 different customer groups. Each customer in the system, and each trunk, is associated with a customer group when a customer group is initially configured. The customer group that is used for a particular call is determined based on: 1) the customer placing the call; and 2) the trunk that received the call.

For emergency calls, a specific customer group is used to provide the routing translations. For emergency calling, the aircore platform 200 uses emergency translations.

Figure 74 is a flow diagram illustrating emergency call processing using the aircore platform 200. The processing starts as step S100. In step S110, the call is received at the aircore platform 200. The process then moves to step S120. In step S120, the aircore platform 200 determines if the call is an emergency call. If the call is not an emergency call, the process proceeds to step S130 and the call is handled as a normal call. In step S120, if the call is an emergency call, the process moves to step S140. In step S140, the aircore platform 200 converts the location of the mobile unit to a dial-up number. The process then moves to step S150.

In step S150, the aircore platform 200 checks the portion of the customer group associated with emergency calls. The process then moves to step S160. In step S160, the aircore platform 200 determines if the dial-up number from step S140 is in the customer group. If the dial-up number is not in the customer group, the process proceeds to step S170, and the call is routed to a default emergency center. If the dial-up number is the customer group, the process moves to step S180. In step S180, the aircore platform 200 changes the dial-up number to an emergency center number. The process then moves to step S190. In step S190, the call is routed to the emergency center. The process then moves to step S200 and ends.

The aircore platform 200 can also support other communication features. For example, the aircore platform 200 may be used with a long-distance resale system.

The aircore platform 200 can also be used to provide microcellular wireless networks in combination with land-line local networks or private branch exchanges (PBX). There are several standards including computer supported telecommunications applications (CTSA), windows telephony application programming interface (TAPI), and telephony services application programming interface (TSAPI), for example, that allow a PBX to incorporate equipment and features from outside vendors. These protocols also allow for call control and routing

decisions to be made by a system that is external to the PBX. The external system can be used to allow for connectivity, feature processing, and seamless number management that allows customers to use both the PBX infrastructure and a separate wireless system using one telephone number and one customer feature profile.

The aircore platform 200 provides an external control function to integrate a wireless system, or microcell, and a PBX using the technique of third party call control. Figure 75 is a diagram illustrating first party call control. In Figure 75, an application 2010 controls a call from a PBX 2011 to a telephone 2014. The control of the call is related to each of the signals and messages passed between the telephone 2014 and the PBX 2011. First party call control is often used as a call control feature in private branch exchanges.

Figure 76 illustrates third party call control. In Figure 76, a call control application 2015 provides direct control over termination of a call to the resource such as the telephone 2014. Calls into a PBX 2016 are routed under the control of the call control application 2015. The aircore platform 200 can incorporate the concept of third party call control to add on to the functionality of a PBX. In particular, the aircore platform 200 may be used with a PBX to add in-building wireless communication capabilities to an existing wired private branch exchange.

A standard PBX interface control element (SPICE) may be added to the aircore platform 200 to provide an interface to a PBX. The SPICE includes software that can operate with the control protocols of different PBXs. The SPICE interfaces internally with the HLR 424 and the SCR 314 (see Figure 10). A system operator may interface with the SPICE using a graphical user interface (GUI).

The SPICE provides third party call control messaging needed to provide the notice of an incoming call, decide how to handle the incoming call and send the appropriate commands to route the incoming call to the correct destination. The SPICE may be co-located with the HLR 424, and requires the basic retrieval capabilities of the HLR 424. The customer profile information in the HLR 424 allows the SPICE to determine how to handle a call. For example, the customer profile may

indicate the operational modes for the customer's wired and wireless telephone handsets.

Customers whose PBX incorporates wireless features, including the SPICE, noted above, may designate one or more operational modes for their telephone handsets. Customers may elect to have incoming call terminate at their desktop telephone first. If the desktop telephone is not available, the call may be routed, via a MSRN, to the customer's mobile unit. Second, the call may be first routed to the mobile unit. If the mobile unit is not available, the call may be routed to the desktop telephone. Third, the call may be routed to the customer's mobile unit only. Fourth, the call may be routed to the customer's desktop telephone only. Fifth, the call may be routed to the mobile unit only when operating in the mobile unit's 112 home area.

One advantage of this arrangement is that the HLR 424 may house the full suite of call forwarding features, voice mail and announcements. The customer's profile determines how the call is handled.

If the customer profile indicates that incoming calls are first routed to a mobile unit, the HLR 424 will locate the customer in the telecommunications network and then have an MSRN allocated to deliver the call to the switch where the customer's mobile unit is residing.

If the customer profile lists the desktop telephone as the first call delivery option, the SPICE determines that the call should be terminated to the desktop telephone. If the customer answers the desktop telephone, SPICE's involvement in the call ends. However, if the customer does not answer at the desktop telephone, SPICE processing can determine the appropriate handling for the call. The call could be routed to the mobile unit, voice mail, or an announcement, for example.

Figures 77 - 79 illustrate call routing for various call entry points. In Figure 77, a PBX 2020 receives an incoming call from a PSTN (not shown). The PBX 2020 uses third party call control over a CSTA interface (not shown) to notify (2022) a HLR 2030 that a customer has received an incoming call 2021. The HLR 2030 determines that the customer is currently roaming on another wireless telephone

system, and that the call needs to be delivered to the customer. Using standard mobile application messaging, the appropriate number for the delivery is allocated and sent (2023) to the PBX 2020. Via the CSTA interface, the PBX 2020 is commanded to send the call over the PSTN with the delivery number as the destination. The call arrives at a local MSC 2025 and is delivered (2037, 2038) via a wireless network 2035 to a mobile unit 2036.

Figure 78 shows a scenario for call delivery to the mobile unit 2036 when the local MSC 2025 is the point of entry for the call from the PSTN (not shown). An incoming call 2040 is received from the PSTN at the local MSC 2025. The MSC 2025 communicates (2041) with the HLR 2030 for call delivery information. The HLR 2030 determines that the customer is roaming on another wireless network 2035 and that the call should be delivered to the wireless network 2035. The appropriate number for delivery is allocated and sent (2039) to the MSC 2025. The MSC 2025 then delivers (2042, 2043) the call to the mobile unit 2036.

Figure 79 shows a scenario for call termination to a desktop telephone. In Figure 79, the local MSC 2025 receives an incoming call 2045 from the PSTN (not shown). The MSC 2025 communicates with the HLR 2030 for call delivery information. The HLR 2030 determines that the customer is not registered in the wireless network 2035 and determines that the call should be terminated to the PBX 2020. The HLR 2030 allocates (2047) a delivery number for the PBX 2020. Using standard procedures, the HLR 2030 sends the delivery number to the MSC 2025. The MSC 2025 then delivers (2048) the call 2045 to the PBX 2020. Using third party call control, the HLR 424 associates the call 2045 with a customer and the call 2045 is terminated to the desktop telephone 2014.

Figure 80 shows an aircore platform 2200 that is used to provide an in-building wireless and wired telephone system with third party call control. A building 2210 includes a PBX 2211. The PBX 2211 connects to wired telephones 2212. The building 2210 also includes a microcellular wireless network 2201 serving mobile units 2213. The PBX 2211 connects to the aircore platform 2200 via wired a

connection and a suitable interface such as a RS-232 interface. The aircore platform 2200 includes a base station controller 2206 and a suitable interface to provide wireless communication to the microcellular network 2201. The BSC 2206 may be incorporated as a component on a card in the aircore platform 2200. A separate database 2205, containing information related to customers of the building 2210 may be provided with the aircore platform 2200. Alternately, the data may be included in a home location register in the aircore platform 2200. Finally, macro cellular systems, such as the extended wireless network 2220 with cells 2221 and 2222 may exist external to the microcell 2201.

In operation a customer using both a wired telephone 2212 and a mobile unit 2213 may specify, by entry in the database 2205, for example, which of the wired telephone 2211 and mobile unit 2213 should receive a call. Thus, when a call comes in to a particular customer, the aircore platform 2200 will determine which of the wired telephone 2212 and the mobile unit 2213 to connect to first. The aircore platform 2200 can be further instructed that when the mobile unit 2213 is active, or in a power-on state, all calls should first be routed to the mobile unit 2213. If the mobile unit 2213 does not respond after a certain number of rings, the incoming call can then be routed to the wired telephone 2212. The microcellular network 2201 may also be used for visitors to the building 2210. In this case, a visitor having a mobile unit may have that mobile unit initiate a registration notification when the mobile unit enters the microcellular network 2201. Then, any incoming calls to the visitor's mobile unit will be routed through the aircore platform 2200 to the microcellular network 2201.

When a customer of the building 2210 transits from the microcellular network 2201 to the external wireless network 2220, a location update is performed that deletes the customer's location in a VLR of the microcellular network 2201, and initiates a registration notification with the mobile switching center of the external wireless network 2220. In this way, the exact location of the mobile unit 2213 may be maintained so that calls to a particular customer may be routed in accordance with the customer's routing plan contained in a VLR/HLR or the database 2205.

In the arrangement described above, a particular mobile unit 2213 and wired telephone 2212 may share a common telephone number. In an alternate arrangement, the wired telephone 2212 and mobile unit 2213 may have different telephone numbers.

A microcellular network, such as the microcellular network 2201, may also be adapted for use in large buildings, such as indoor stadiums and convention centers. A mobile switching center such as the aircore platform 2200 may incorporate multi-protocol processing and base stations so that visitors to the convention center may use mobile units inside the convention center regardless of the protocol established for the mobile unit. The aircore platform 2200 may be configured to charge different rates for different visitors to the convention center. People who work in the convention center may be charged yet another rate for using mobile units in the convention center.

The aircore platform 200 may incorporate fault resilient features, which may be particularly desirable for distributed wireless systems. The fault resilient hardware architecture of the aircore platform 200 may be logically split into three layers as shown in Figure 81. A hardware architecture 2300 includes a computing element layer 2310. The computing element layer 2310 includes computing elements 2311 and 2312. The computing elements 2311 and 2312 are connected by an appropriate communications medium such as an ethernet 2313. The ethernet 2313 may have a capacity of 100 Mb or more, for example.

An input/output (I/O) processor layer 2320 includes I/O processors 2321 and 2322. The I/O processors 2321 and 2322 are connected by an appropriate communications medium such as a 100 Mb ethernet 2323. The I/O processors 2321 and 2322 are both connected to each of the computing elements 2311 and 2322 by an appropriate communications medium such as a 40 Mb fiber optic cable 2314.

A telephony interface processor (TIP) layer 2340 includes a plurality of telephony interface processors (TIPs) 2341_1 - 2341_n. The TIPs 2341_1 - 2341_n are connected by a dual rail ethernet 2343. The ethernet 2343 is also used to connect the TIPs 2341_1 - 2341_n with the I/O processors 2321 and 2322.

The three layers described above comprise the three main processing areas of the aircore platform 200. Communications between the three layers provides for a variety of physical layouts and geographical configurations. For example, the fiber optic connection between the computing element layer 2310 and the I/O processor layer 2320 can be geographically separated by 1.5 kilometers or more. The TIPs 2341_1 - 2341_n can be spread geographically and remotely controlled via a centralized computing element layer and I/O processor layer set. Thus, the aircore platform architecture 2300 can be adapted to provide a large distributed wireless network with centralized control or the layers can be co-located.

Figure 82 shows the logical construction of the computing element 2311 in more detail. The computing element 2312 is identical to the computing element 2311 and therefore, only the computing element 2311 will be described. The computing element 2311 includes a central processor 2315, a memory 2316 and a PCI-based connector 2317 that couples the computing element 2311 to the I/O processors 2321 and 2322. Also shown is a memory 2318 that stores the software applications that operate in the computing element 2311. The software applications are described with reference to Figure 10. The memory 2316 may be a random access memory (RAM), for example. The memory 2318 may be a read only memory (ROM), for example.

Figure 83 shows the logical construction of the I/O processor 2321 in more detail. The I/O processor 2322 is identical to the I/O processor 2322 and therefore only the I/O processor 2321 will be described. A PCI interface 2332 connects the I/O processor 2321 to the ethernet 2314. A memory module 2326 includes a hard disk 2327, an interface slot 2328 for a CD-ROM, and an interface 2329 for a floppy disk. A memory 2325 includes the programming to operate the I/O processor 2325. A central processor 2324 controls operation of the I/O processor 2325. An ethernet interface 2330 provides connections to the ethernet 2323 and to the dual rail ethernet 2343. A memory 2333 stores application programs executed by the I/O processor 2321. Finally, SS-7 interface modules 2334 and 2335 provide connections to systems external to the aircore platform 200.

Figure 84 shows the logical construction of the TIP 2341_1. The other TIPs are the same as the TIP 2341_1. A central processor 2344 controls operation of the TIP 2341_1. A memory 2345 includes the operating programs for the TIP 2341_1. A memory 2348 includes the application programs under control of the TIP 2341_1. The application programs are described with reference to Figure 10. An interface 2347 connects the TIP 2341_1 to the dual rail ethernet 2343. A memory module 2346 includes a hard drive 2349 and a floppy disk interface 2350. An external interface module 2349 connects the TIP 2341_1 to systems external to the aircore platform 200.

Figure 85 shows another hardware embodiment of the aircore platform 2400. In this embodiment, the aircore platform 2400 includes a 19-inch rack-mountable chassis 2410. The aircore platform 2400 includes dual loadsharing power supplies 2420 and optional power supplies 2422. The chassis also includes dual mirrored SCSI disk drives 2430 and optional drive bays 2432. An I/O processor board 2440 connects to telephony boards slots 1-14 for telephony boards 2470-2485. Finally, the aircore platform 2400 includes a removable fan tray 2490.

Figure 86 shows the I/O processor in more detail. The I/O processor board 2440 includes a processor 2441 that provides bus control for the telephony boards 2470-2485. The processor 2441 can be an advanced processor such as an Intel Pentium™ family processor or other processor. The I/O board 2440 also includes a scalable random access memory 2442. The I/O processor board 2440 provides on-board PCI video 2443, IDE 2444 and SCSI drive controllers 2445, and multiple serial I/O ports 2446. Also included are Ethernet connections 2447, floppy disk drives 2448, and PCMCIA slots 2449. The I/O processor board 2440 provides front and rear access to the I/O devices. The SCSI drives 2445 may be dual mirrored 1.5 Gb hard drives. The SCSI drives 2445 may be configured in a RAID-1 format. The SCSI drives 2445 are hot swapable and can be resynchronized in case of failure.

The aircore platform 2400 may provide for local network connectivity and dial-out access using a standard 10base-T or 100base-T Ethernet connection for LAN connecting options and a 56k dial-up modem for remote access dial-in capability.

Other advanced telecommunications connection devices may also be used with the aircore platform 2400. Standard telephony boards may be used with the aircore platform 2400 for T-1/E-1 and ATM communications. For example, the telephony boards 2470-2485 include TH-B1240 OCTAL T-1/E-1 interface boards for common channel signaling based T-1s. TH-BD96 quad T-1 interfaces are provided for channel associated signaling using T-1s. TH-BD120 quad E-1 interface devises are used for channel associated signaling using E-1s. TH-BV30 voice I/O provides 30 ports of I/O and signal processing. TH-BC64 provides conferencing capabilities. A TH-BSS7 board provides both DS0 and V.35 connections. Each of the telephony boards 2470-2485 provides 4-6 trunk links. Also connected to the aircore platform 2400 are operator interface devices including a monitor 2491, a keyboard 2492, and a mouse 2493.

The switching architecture of the aircore platform 2300 or 2400 may be the H.110/H.100 based standard, for example. The H.110 and the H.100 switching matrix is a standard Application Specific Integrated Circuit (ASIC) that resides on each board in the system. This means that rather than shipping all interface channels to a single point in the system to make and break the connections for switching, each board controls its own switching. The H.110 switching matrix uses a J4 connector or connects to the other components of the aircore platform 2400 using a J4 connector on a back plane of the chassis 2410. There may be a total of 32 streams running at speeds of $8MH_z$ Each stream provides 128 channels of 64 kbps. Total bus capacity ranges from 512 to 4096 channels.

The H.100 switching matrix uses a ribbon cable to connect to boards together to provide the actual streams of digitized channels. There are a total of 32 streams running at speeds of $2MH_z$ to $8MH_z$. Each stream provides from 32 to 129 channels of 64 kbps. The total bus capacity ranges from 512 to 4096 channels.

Other switching matrices may also be used with the aircore platform 2400.

The capacity of the aircore platform 2400 may be extended. Multi-chassis configurations can be provided to claim the switch matrices together. This may be

accomplished using several standard multi-chassis interconnection interfaces or by connecting the chassis via E-1 or T-1 connections. The addition of ATM allows for a standard extension mechanism to the switch matrix between chassis.

Other hardware configurations besides the two embodiments described above are available with the aircore platform 200.

The aircore platform 200 incorporates graphical user interfaces (GUIs) to aid operator manipulation of system data. Figures 87-119 show the hierarchy of windows used with the GUIs and also show examples of GUI screens used with the aircore platform 200.

Figure 87 shows the hierarchy of windows used with the aircore HLR 424. A hierarchy 3000 includes a home location register icon screen 3001 which is initially displayed. Upon entry of a password in a password screen 3002, a home location register access screen 3003 is displayed. Using the home location register access screen 3003, an operator can choose one of the screens 3004-3009 for GSM, CDMA, TDMA, AMPS, multi-mode protocols, or for prepaid services. Finally, corresponding to each of the wireless protocols is a separate prepaid screen 3010-3014.

GSM subscriber profiles are configured as per the GSM feature set. CDMA subscriber profiles are configured as per the CDMA (IS-664) feature set. Multi-mode subscriber profiles may be configured for multiple air interfaces. Multi-mode subscribers use the common feature set between the GSM, CDMA, TDMA and AMPS protocols. All of the above subscriber profiles can incorporate prepaid feature functionality.

Prepaid subscriber profiles are configured as strictly prepaid in the aircore system. Prepaid subscribers may use wireless or wireless prepaid features.

Figure 88 shows the GSM subscriber window 3004 in more detail. A number of subscribers block 3021 lists the current number of subscribers in the HLR 424 as well as the capacity of the HLR 424. The subscriber list 3022 individually lists the subscribers to the aircore systems. A previous button 3025 and a next button 3026 loads the previous or next group of subscribers into the subscriber list scroll box 3022.

A properties button 3023 allows modification of data for the selected subscriber. A search button 3024 allows for search of the HLR 424 when a subscriber MSISDN number is input at the search line. An add button 3027 and a delete button 3028 allow the addition or deletion of a subscriber profiled in the HLR 424. A report button 3029 allows an operator to view a change report file created for HLR 424 modifications.

Figure 89 is an example of an individual subscriber profile for a GSM subscriber. The subscriber profile 3030 includes a customer and mobile unit identification block 3031, call offering block 3032, call restriction block 3033, and call restrictions block 3034. Also included is a call features block 3035, and line identification block 3036.

Subscriber profiles for other wireless protocols are similar to that described above for a GSM subscriber.

Figure 90 shows a routing administration windows hierarchy 3110 associated with establishing routing translations in the aircore systems. The initial screen is a database management icon screen 3101. Next, a routing administration tab 3102 is display. Linked to the routing administration tab 3102 is a customer group properties screen 3103. Also linked to the routing administration tab 3102 is a standard routing screen 3104, a feature codes screen 3105, an emergency call routing screens 3106 and a tones and announcement screen 3107. The data displayed in the screens 3104-3107 may be modified by displaying an add/modified/delete screen 3108.

Figure 91 shows the routing administration tab 3102. A customer group scroll box 3111 shows the customer groups that are currently active in the aircore system. The customer group is a required piece of data that is assigned to both customers and trunk groups. The number assigned is used as an index into the appropriate routing table for processing an incoming call. The routing translations determine the allowable calls, the type of call, and the appropriate system routing for the call. Each customer group can accommodate hundreds of individual from-to routing translation entries. The translations can provide support for any dialing plan between 1 and 32 digits. Dialing plans of varying lengths maybe configured within the same customer

group. Each line of translations within each customer group provides a primary and alternate route based on the trunk group. In addition, each route is provided its own digit manipulation parameters (strip and prefix digits). The aircore system can accommodate up to 100 customer groups.

Figure 92 shows a customer group modification window 3120. The customer group modification window 3120 defines the overall properties associated with a particular customer group. Check boxes 3121 allow for the configuration of three alternate types of translations.

Figure 93 shows the standard routing translation window 3104. A scroll box 3131 is used to display portions of the information. The information displayed in the scroll box 3131 includes "from" data, which is the number the range starts from; "to" data, which is the number the range ends at; min, which is the minimum length of the digit string; max, which is the maximum length of the digit string; and type, which is the type of call the number range indicates. Also shown is the route number of the trunk and the numeric trunk group number.

Figure 94 shows the standard routing translations modifications window 3108. The standard routing translations modifications window 3108 provides the operator access to modify the selected number range. The window is used for adding or modifying ranges in the standard routing translations window 3104.

Figure 95 shows the feature code routing translation window 3105. The feature code routing translation window 3105 includes a scroll box 3151 that displays a portion of the information selected by the operator. The feature code routing translation window 3105 contains the information related to routing feature manipulation calls for the aircore system. The parameters supplied in the feature code routing translation window 3105 are used to determined the type of feature manipulation and the appropriate system action.

Figure 96 shows the emergency call routing translations window 3106. A scroll box 3161 displays currently selected information. The information includes "from" data which is the number the digit range starts from. The "from" data can be

indicated by a code such as 911 or can be represented as a cell site. The aircore system operator can use the emergency call routing translations window 3106 to route all emergency calls to a specific number or to establish a trunk group used exclusively for emergency call routing.

Figure 97 shows the treatment routing translations window 3107. The treatment routing translation window 3107 contains information relate to routed calls, which are to be treated to an appropriate treatment option, which may be a tone or announcement. In Figure 97, a scroll box 3171 includes an ID, which is the number of the treatment in the aircore system, a description 3172, which is the alpha-numeric description of the treatment, a first option (1st Route) 3173, which is the first option for treating the call (typically configured to an announcement or tone) and a second option 3174, which is the second option to use if the first option 3173 is not available (typically set to a standard tone). Failure to use the first option 3173 indicates that all of the announcement resources are currently in use.

The aircore system includes graphical user interfaces that allow the operator to perform maintenance actions on individual trunks in the system. When this option is chosen in an administration pull down menu (not shown), the operator first selects the appropriate span and channels, then executes maintenance commands as required. Figure 98 shows the hierarchy of windows used for trunk maintenance. In Figure 98, the hierarchy 3200 includes a control panel window 3201, an administration window 3202, a facilities selection window 3203, and a digital trunk maintenance window 3204.

Figure 99 shows the facilities selection window 3203. The window 3202 allows an operator to select the appropriate facilities in the aircore system to be viewed for maintenance actions.

Figure 100 shows the digital trunk maintenance window 3204. The digital trunk maintenance window 3204 allows the operator to view the trunk configuration of a particular span and to change the state of the channels on that span. In the window 3204, data that is grayed out represents non-configured channels. Channels

can be configured via a system configuration option on the administration pull-down menu. Figure 100 shows the digital trunk maintenance window for T-1 trunk maintenance. A similar window is available for E-1 trunk maintenance.

Figure 101 shows the aircore configuration windows hierarchy 3300. The system configuration 3301 is accessed from a control panel graphical user interface (not shown). This allows the operator to access setup and configuration files. The operator has access to the configuration of both hardware and software parameters associated with system operation. Subordinate windows in the system configuration hierarchy 3300 include a trunk group window 3302 and a board configuration window 3303. Associated with the trunk group window 3302 is a trunk group configuration window 3304. Associated with the board configuration window 3303 is a T-1/E-1 board configuration window 3305, a voice I/O window 3306, a conference window 3307, a SS7 window 3308, and an analog window 3309 and span configuration windows 3310 and 3312.

Trunk group configuration is part of the system configuration of the aircore GUI. A trunk group is a logical assignment of characteristics to physical resources in the aircore system. Trunk groups are used to inform both the low level and high level software in the aircore system of how to process a call. Trunk groups also allow the operator to partition the system for specialized use by groups or subscribers. Figure 102 shows the trunk group selection window 3302. A properties button 3322 is used to access the trunk group configuration window 3304.

Figure 103 shows the trunk group configuration window 3304. When a valid trunk group number is input in the selection window 3302, and the property button 3322 is pushed, the configuration window 3304 appears. The trunk group configuration window 3304 includes the sequential number assigned to the trunk group and an alpha-numeric name associated with the trunk group. The name given to the trunk group is used to identify the individual circuits configured within the trunk group.

Figure 104 shows the board configuration window 3303. The aircore board level configuration is accomplished via the board configuration window 3303 and subordinate windows. The board configuration window lists the possible board slots in the hardware component (installed or not) in a particular slot. To access the configuration of the particular board, the operator selects a desired board and operates the property button 3332.

Figure 105 shows the T-1/E-1 board configuration window 3305. A span click box section 3381 allows an operator to choose which span to configure. The window 3305 is used for configuration of the T-1 and E-1 boards in the aircore system. Based on the board type selected, the appropriate number of spans and channels are accessible to the operator for configuration. The window shown in Figure 105 is used for configuration of the 4-span T-1 board, for the CPCI and PCI bus types. Similar windows are used for other span and channel configurations.

Figure 106 shows the T-1/E-1 span configuration window 3310. The T-1/E-1 span configuration window 3310 appears when a span (A-H) is selected from click box 3381 in the T-1/E-1 board configuration window 3305 shown in Figure 105. The window 3310 contains the data associated with a particular T-1 or E-1 span on the board. Similar windows are available for other span configurations.

Figures 107-109 show the windows for the voice I/O board configuration, the conference board configuration, and the SS-7 board level configuration. These windows are similar to that shown in Figure 106.

The aircore system generates call detail records (CDRs) to track system resource usage and call traffic for customers. Each CDR contains information pertaining to a particular part of a call. A CDR is a record created whenever there is call activity on the aircore system. The CDR manager is a subsystem in the aircore system responsible for generating and storing this information. The CDR manager provides the operator with a complete set of options for viewing data both real time and archive, monitoring traffic on the aircore system, and retrieving the data for off-system archival. Figure 110 shows the hierarchy of windows used for call record

management. The hierarchy 3500 includes the call record manager window 3501, archive window 3502, configuration window 3503, and billing window 3504. The billing window 3504, and associated lower level windows, are only available if the prepaid wireless package is configured. Associated with the configuration window 3503 are output selection window 3507 and auto removal window 3508. Associated with the billing window 3504 is distributor selection window 3506 and bill generation window 3509. The call record manager window 3501 provides operator access to view, process or redirect call detail record outputs on the aircore system.

Figure 111 shows the archive window 3502. The archive window 3502 allows the operator to view and direct archived output of call detail records that have been created on the aircore system.

Figure 112 shows a configuration window 3503. The configuration window 3503 allows the operator to determine the real time output destination for call detail records. Regardless of the output type selected, a file containing the call records on disk is always created. In addition, the operator has the ability to configure the auto removal period for the call detail records. Using the output selection window 3507, the operator can send an output to a display or a printer, for example.

Figure 113 shows the auto removal window 3508. Using the auto removal window 3508, the operator can set the number of days that the call detail record will be archived on the system. The number of days the call detail records are stored on the aircore system before automatic removal can be set a value between 1 and 180 in increments of one day.

The aircore platform 200 can provide, as an option, fully integrated prepaid functionality. This functionality can span across both wireless and wireline applications providing a seamless prepaid system. Furthermore, this functionality is provided as an integrated software feature, saving the cost and maintenance of a separate off-board prepaid system. The prepaid system feature package provides full functional real time debiting for aircore customers complete with a full billing package and a comprehensive rating schedule. Figure 114 shows the rating

administration window hierarchy 3600 that is used in conjunction with the aircore prepaid system. A database management icon screen 3601 is shown initially. Next, a rating administration window 3602 is displayed. A distributor data window 3603 and a distributor properties window 3606 can be selected from the rating administration window 3602. Finally, from the distributor data window 3603, an add/modify/delete rate window 3605 can be accessed as well as individual rate plans 0-9 360 $_{i-n}$ with associated add/modify delete rate windows 3607 $_{i-n}$. The aircore prepaid system accommodates ten rate plans.

Figure 115 shows the rating administration window 3602.

Figure 116 shows the add/modified/delete rate window 3605. A distributor number box 3621 shows the number assigned to a distributor when added to the system. A default rate plan box 3622 shows the rate plan used as the default for subscribers added for the distribution shown in the distributor number box 3621. The default rate plan is used when a rate plan is not explicitly assigned. A description window 3623 provides the name and/or a description of the distributor shown in the distributor number box 3621.

Figure 117 shows distributor data modification window 3603. The distributor data modification window 3603 allows for the configuration of the land charges rate plans used for real time billing on the aircore system. The window 3603 is accessed on a per distributor basis. Distributor data includes access to land charges and configured access to rate plans. In addition to a default rate plan, each distributor can have up to ten different rate plans. Each rate plan specify specific air time rating structures. Land charges are specified on a per distributor basis.

Figure 118 shows a rate plan window 3607. From the distributor data modification window 3603 shown in Figure 117, if an active rate plan button is selected, the rate plan window 3607 appears. The rate plan window 3607 provides the operator with the ability to configure the air time charges associated with a specific rate plan. The rate plan window 3607 also provides the ability to specify any exceptions to the main distributor land based charges. Data specified in the rate plan

window 3607 overrides the date in the distributor window 3603 and allows an operator to specify unique plans for both land and air time rates without adding a new distributor each time.

Figure 119 shows a country entry window 3640. The country entry window 3640 allows modification of rates charges for the land portion of the call. These charges are based on a first and additional minute rate to each location around the world.

Figure 120 shows a debit subscriber profile window 3650. The debit subscriber profile window 3650 is used to input debit specific subscriber data for accounts. The window 3650 is accessed via the debit button on a main subscriber profile window (not shown). The fields of the window 3650 specify the parameters used for real time billing and account information for the subscriber. The window 3650 opens as an overlay on the subscriber profile window and allows the subscriber number, name, customer group and serial numbers to be viewed when editing the debit subscriber profile window 3650. A balance section 3651 includes the current amount, which is the current balance in dollars for the individual subscriber account. This amount is incremented based on the subscriber usage. Subscriber access is cutoff when the current amount is equal to the credit limit. The credit limit is the maximum amount in dollars for the subscriber account. The credit limit is compared against the current amount value to determine if access to the account is allowed. If the current amount field equals the credit limit field, access to the account is not allowed. The payment method field specifies the method of payment for the account. The payment method can be cash, credit or other. If credit chosen, the credit card fields must be filled in. The debit subscriber profile window 3650 also includes a credit card section 3652. The credit card section 3652 includes the credit card number (if applicable) the type of credit card and the expiration date of the credit card. Other information provided in the debit subscriber profile window 3650 includes the distributor and rate plan and billing methods chosen for this customer.

The billing window 3504 (see Figure 110) provides access to customer billing records. The billing window 3504 is accessed from the menu bar of the call record manager window 3501. When selected, the distributor selection window 3506 shown in Figure 21 is displayed. The distributor selection window 3506 allows an operator to select a distributor for a billing calculation. The distributor selection window 3506 provides access to the billing generation window 3509.

The aircore system provides for the configuration of up to twenty different language files for assignment to customers or for announcements. Figure 123 shows a languages administration window 3680. The languages administration window 3680 provides operator access to a language configuration database in the aircore system. The language configuration window 3680 is accessed from the database management icon screen 3101 (see Figure 90).

Figure 122 shows the billing generation window 3509. The billing generation window 3509 allows access to individual subscriber bills and invoices as well as location summaries of customer usage. Billing information is accessed on the basis of the location summoned.

While this invention has been described in conjunction with the specific embodiment outlined above, it is evident that many alterations, modifications and variations will be apparent to those skilled in the art. Accordingly, the preferred embodiments of the invention as set forth above are intended to be illustrative, not limiting. Various changes may be made without departing from the spirit and scope of the invention as defined in the following claims.

In the Claims:

1. A switching center for a communications system that provides communications services to customers having wireless and other communications devices, comprising:

a first interface, the first interface receiving and sending digital messaging having a first protocol;

a second interface, the second interface receiving and sending digital messaging having a second protocol; and

a processor system coupled to the first and the second interfaces, wherein the processor system controls operation of the first and the second interfaces and generates control messages for sending by the first and the second interfaces.

2. The switching center of claim 1, wherein the first interfaces comprises:

a first intrasystem message handler; and

a first intersystem message handler, and wherein the second interface comprises:

a second intrasystem message handler; and

a second intersystem message handler.

3. The switching center of claim 2, wherein the first intrasystem message handler operates according to IS-634 protocols, the second intrasystem and intersystem message handlers operate according to GSM protocols, and the first intersystem message handler operates according to IS-41 protocols.

4. The switching center of claim 3, wherein the GSM protocols include GSM A (Series 4 and 8) protocols, IS-651 and J-STD protocols, IS-652 protocols and GSM 09.02 protocols.

5. The switching center of claim 3, wherein the IS-634 and the IS-41 protocols include time division multiple access (TDMA) protocols and code division multiple access (CDMA) protocols and AMPS protocols.

6. The switching center of claim 1, wherein the first interface further receives and sends analog messaging, the analog messaging including Advanced Mobile Telephone System (AMPS) protocols.

7. The switching center of claim 6, wherein the AMPS protocols include IS-634 protocols and ISDN PRI+ protocols and proprietary protocols.

8. The switching center of claim 1, further comprising:

a home location register coupled to the processor system; and

a visitor location register coupled to the home location register and the processor system, wherein the home location register stores permanent data related to customers of the communications system that are homed on the communications system, and wherein the visitor location register stores temporary data related to customers that are active on the communications system, the home location register and the visitor location register indicating a most recent protocol used by a wireless communications device of a customer and indicating other protocols useable by the wireless communications device.

9. The switching center of claim 8, wherein the permanent data related to customers in the home location register is stored in a customer profile, the customer profile including one or more of call features, call restrictions, mobile unit protocols, line identification, personal identification number, call offering, prepaid services and customer information.

10. The switching center of claim 8, wherein the home location register includes a common data section and protocol-specific data sections, wherein the common data section stores data generic to all protocols and the protocol-specific data sections stores data unique to one or more specific protocols.

11. The switching center of claim 8, wherein the processor system determines a protocol of a wireless communications device by reference to one of the home location register and the visitor location register.

12. The switching center of claim 1, wherein the communications system includes one or more base stations, and wherein the processor system determines a protocol of

a wireless communications device based on a protocol of the base station that communicates between the switching center and the wireless communications device.

13. The switching center of claim 1, wherein the communications system includes a multi-protocol base station, the multi-protocol base station sending base station control messages to the switching center, and wherein the processor system determines a protocol of a wireless communications device by interpreting protocol data contained in the base station control message.

14. The switching center of claim 1, wherein the communications system receives communications from an external wireless system having an external home location register and an external communications device registered on the external home location register, and wherein the processor system determines a protocol of the external communications device by obtaining an identification of the external home location register.

15. The switching center of claim 1, wherein the processor system generates and interprets generic command messages, the generic command messages operable to control the communications services according to at least the first and the second protocols.

16. The switching center of claim 1, wherein the processor system generates and interprets protocol-specific command messages, the protocol-specific command messages used to provide additional control of the communications services.

17. The switching center of claim 1, further comprising an asynchronous transfer mode (ATM) interface, the ATM interface providing wireless ATM communications and other packet board communications.

18. The switching center of claim 1, further comprising a public switched telephone network (PSTN) interface.

19. The switching center of claim 1, further comprising a private branch exchange (PBX) interface.

20. The switching center of claim 1, wherein the wireless communications devices include a fixed wireless telephone, a mobile telephone and a computer having a wireless modem.

21. The switching center of claim 1, further comprising:

an equipment identification register, wherein the equipment identification register includes serial number data related to the mobile communications devices that are homed on the wireless communications system; and

an authentication center, wherein the authentication center provides authentication and encryption parameters for wireless communications received at and originated from the switching center.

22. The switching center of claim 1, further comprising:

a first device handler coupled to the first interface; and

a second device handler coupled to the second interface, wherein the first and the second device handlers are operable to receive and transmit multi-protocol messaging from and to devices external to the switching center and to transmit and receive generic messaging to and from the first and the second interfaces, respectively.

23. The switching center of claim 1, wherein the processing system comprises:

a central processor, the central processor controlling operation of the processor system;

an authentication and registration system, the authentication and registration system controlling registration of the wireless communications devices with the communications system and providing encryption and ciphering of voice and data communications;

a paging system, the paging system sending paging messages to the wireless communications devices and receiving page response messages from the wireless communications devices;

a timer system, the timer system setting timers in response to operations of the processing system;

a recovery and startup system, the recovery and startup system managing a status of communications trunks in the communications system and performing audits of the communications system; and

a memory, wherein the memory stores information related to a particular call in a memory area, and wherein components of the processor system access the memory area to retrieve and store information related to the particular call.

24. The switching center of claim 23, wherein the processor system further comprises a hand off processor, the hand off processor receiving and processing hand off requests from a wireless communications device in the communications system, determining a target base station for hand off and sending a hand off command to the wireless communications device.

25. The switching center of claim 23, wherein the processor system operates to reserve a voice channel with each base station in the communications system that is capable of receiving communications from the wireless communications device, and wherein the processor system operates to release all base stations having a reserved voice channel, except the target base station, upon receipt by the processor system of a call connect acknowledge message.

26. The switching center of claim 1, further comprising a graphical user interface, the graphical user interface providing an operator access to operate the switching center and to update data related to the customers, database configuration, system configuration and maintenance.

27. A mobile switching center, comprising:

a central processor that processes incoming signals, wherein the incoming signals are switched in a telecommunications network; and

a wireless interface module that supports two or more wireless protocols.

28. The mobile switching center of claim 27, further comprising a switch management module that manages the switching of the incoming signals.

29. The mobile switching center of claim 27, wherein the wireless interface module comprises a digital interface that supports digital wireless communications.

41. The mobile switching center of claim 27, further comprising an equipment identification register which stores information identifying equipment used with the mobile switching center.

42. The mobile switching center of claim 27, further comprising a prepaid module that enables prepaid communication.

43. The mobile switching center of claim 27, further comprising a features module that supports a plurality of communication features.

44. The mobile switching center of claim 27, further comprising a remote network management access module that is remotely located from and operably connected to the mobile switching center.

45. The mobile switching center of claim 27, further comprising an authentication center that authenticates incoming signals.

46. An advanced intelligent message handler for use in a mobile telecommunications network having mobile communications devices and one or more base stations, the advanced intelligent message handler, comprising:

a first interface for intersystem messaging, the first interface, comprising:

a first GSM processing thread,

a first TDMA processing thread,

a first CDMA processing thread, and

a first AMPS processing thread;

a second interface for intrasystem messaging, the second interface, comprising:

a second GSM processing thread,

a second TDMA processing thread,

a second CDMA processing thread, and

a second AMPS processing thread; and

a processor system coupled to the first and the second interfaces, the processor system controlling a flow of message traffic to and from the first and the second interfaces.

30. The mobile switching center of claim 27, wherein the wireless interface module comprises an analog interface that supports analog wireless communications.

31. The mobile switching center of claim 27, wherein the wireless interface module comprises a GSM interface that supports GSM protocol wireless communications.

32. The mobile switching center of claim 27, wherein the wireless interface module comprises a TDMA interface that supports TDMA protocol wireless communications.

33. The mobile switching center of claim 27, wherein the wireless interface module comprises a CDMA interface that supports CDMA protocol wireless communications.

34. The mobile switching center of claim 27, wherein the wireless interface module comprises a AMPS interface that supports AMPS protocol wireless communications.

35. The mobile switching center of claim 27, wherein the wireless interface module comprises a DAMPS interface that supports DAMPS protocol wireless communications.

36. The mobile switching center of claim 27, further comprising a visitor location register that stores information about visiting switch users.

37. The mobile switching center of claim 27, further comprising a home location register that stores information about home switch users.

38. The mobile switching center of claim 27, further comprising a wired interface module that provides connections to wired land-lines.

39. The mobile switching center of claim 27, further comprising a graphical user interface that allows an operator to operate the mobile switching center.

40. The mobile switching center of claim 39, wherein the graphical user interface is remotely located from the mobile switching center.

customer profile indicating protocols available to the mobile and a most recent protocol used by the mobile unit; and

creating a visitor location register, the visitor location register containing the customer profile for each mobile unit that is active in the multi-protocol wireless network.

55. The method of claim 54, wherein the customer profile further includes call features, call restriction, line identification, personal identification number, call offering and prepaid services.

56. The method of claim 54, wherein the home location register includes a common data section and a protocol-specific data section, the common data section storing data generic to all protocols and the protocol-specific data sections storing data unique to one or more protocols.

57. The method of claim 54, further comprising determining a protocol of a wireless communications device by reference to one of the home location register and the visitor location register.

58. The method of claim 47, further comprising determining a protocol of a wireless communications device by reference to a protocol of a base station that communicates with the switching center.

59. The method of claim 47, wherein the multi-protocol wireless network includes one or more multi-protocol base stations, wherein the processor determines a protocol of a wireless communications device by interpreting protocol data contained in communications from the one or more multi-protocol base stations.

60. The method of claim 47, further comprising:

receiving communications from an external communications device from a wireless network external to the multi-protocol wireless network, the external wireless network including an external home location register; and

determining a protocol of the external communications device by obtaining an identification of the external home location register.

47. A method for controlling communications in a multi-protocol wireless network, comprising:

receiving first digital communications according to a first protocol at a first interface;

sending a first control message according to the first protocol;

receiving second digital communications according to a second protocol at a second interface; and

sending a second control message according to the second protocol, wherein a processor in a switching center interprets the first and the second digital communications and generates the first and the second control messages.

48. The method of claim 47, further comprising;

receiving intrasystem communications at a intrasystem message handler; and

receiving intersystem communications at a intersystem message handler.

49. The method of claim 48, wherein the intrasystem message handler operates according to IS-634 and GSM standards and the intersystem message handler operates according to IS-41 and GSM standards.

50. The method of claim 49, wherein the GSM protocols include GSM A protocols, IS-651 protocols, IS-652 protocols and GSM 09.02 protocols.

51. The method of claim 49, wherein the IS-634 and IS-41 protocols include time division multiple access (TDMA) protocols and code division multiple access (CDMA) protocols and AMP protocols.

52. The method of claim 47, wherein the first interface further receives and sends analog communications, the analog communications including Advanced Mobile Telephone System (AMPS) protocols.

53. The method of claim 52, wherein the AMPS protocols include IS-634 protocols and ISDN PRI+ protocols and proprietary protocols.

54. The method of claim 47, further comprising:

creating a home location register, the home location register including a customer profile for each mobile unit in the multi-protocol wireless network, the

sending and receiving registration notification messages to register a mobile unit in a visitor location register;

sending and receiving paging messages to access a mobile unit in the multi-protocol wireless network;

setting a timer to time out control messages;

maintaining a status of communications trunks in the multi-protocol wireless network; and

storing data related to a particular call in a common memory area, the data for the particular call used by components of the multi-purpose wireless network to control and access the particular call.

72. The method of claim 47, further comprising;

monitoring a signal strength of communications with a mobile communications device;

sending a hand off request when the signal strength exceed a limit;

measuring signal-strengths of each of the other base stations in the multi-protocol wireless network;

reserving a voice channel in each of the other base stations; and

selecting a target base station for communication with the mobile communications device; and

handing off the mobile communications based on the measurements.

73. The method of claim 47, further comprising providing a graphical user interface to the switching center, the graphical user interface allowing an operator to update information stored by the switching center.

74. The method of claim 47, further comprising;

designating a first communications trunk, the first communications trunk carrying the first control message, wherein the first communications trunk connects a first base station and the switching center; and

61. The method of claim 47, wherein the processor generates and interprets generic messages, the generic messages providing generic control signals to control operation of the multi-protocol wireless network.

62. The method of claim 47, wherein the processor generates and interprets protocol-specific messages, the protocol-specific messages providing additional control of the communications devices.

63. The method of claim 47, further comprising providing packet based communications.

64. The method of claim 63, further comprising providing an asynchronous transfer mode (ATM) interface providing wireless ATM communications.

65. The method of claim 64, wherein the ATM interface provides PSTN connectivity and an extension of a switch matrix.

66. The method of claim 47, further comprising connecting the switching center to a public switched telephone network (PSTN).

67. The method of claim 47, further comprising connecting the switching center to a private branch exchange.

68. The method of claim 47, wherein the communications devices include a fixed wireless telephone, a mobile telephone and a computer having a wireless modem.

69. The method of claim 47, further comprising:

recording an identity of a mobile device; and

encrypting and decrypting the first and the second digital communications.

70. The method of claim 47, further comprising:

receiving first communications at and sending first communications from a first device handler coupled to the first interface; and

receiving second communications at and sending second communications from a second device handler coupled to the second interface, wherein the first and the second device handlers are operable to receive and transmit multi-protocol communications.

71. The method of claim 47, further comprising:

designating a second communications trunk, the second communications trunk carrying the second control message, wherein the second communications trunk connects a second base station and the switching center.

75. The method of claim 47, wherein the switching center comprises a plurality of communications trunks, the switching center designating one or more of the plurality of the communications trunks for use in connecting wireless calls.

76. The method of claim 75, wherein the switching center tracks a state of each communications trunk of the plurality of communications trunks.

77. The method of claim 76, wherein a state of a communications trunk may be one of not configured, blocked, unblocked, unblocked pending, call processing, blocked pending and maintenance.

78. The method of claim 77, wherein the communications trunk transitions from the not configured state to the blocked state when a base station is activated in the wireless network.

79. The method of claim 77, wherein the communications trunk transitions from the blocked state to the unblocked pending state based on a recovery request.

80. The method of claim 77, wherein the communications trunk transitions from the unblocked state to the call processing state when a base station is allocated for call processing.

81. The method of claim 47, further comprising:

receiving a call from a prepaid customer;

processing the call from the prepaid customer;

determining an allowed time of call based on a prepaid account for the prepaid customer;

determining a warning time for the call, wherein the warning time is a time less than the allowed time;

connecting the call;

monitoring a time of the call;

providing a warning to the prepaid customer when the warning time occurs; and

disconnecting the call when the allowed time is reached.

82. The method of claim 81, further comprising

providing a plurality of rate plans, wherein the prepaid customer may select a desired rate plan from the plurality of rate plans.

83. The method of claim 82, wherein the desired rate plan is stored in a home location register.

84. The method of claim 81, further comprising

determining a least cost route for the call from the prepaid customer.

85. The method of claim 81, further comprising:

at a completion of the call from the prepaid customer, computing an actual cost for the call; and

updating the prepaid account, based on the actual cost for the call.

86. A graphical user interface (GUI) for use with a scalable, wireless switching center, comprising:

a home location register (HLR) GUI hierarchy;

a visitor location register (VLR) GUI hierarchy;

a database management GUI hierarchy;

a system configuration GUI hierarchy; and

a call record manager GUI hierarchy, wherein GUIs provide access to data that controls operation of the switching center.

87. The GUI of claim 86, further comprising a rate plan hierarchy GUI.

88. The GUI of claim 86, wherein the HLR GUI hierarchy comprises:

a password GUI;

a HLR access GUI; and

protocol-specific HLR GUIs, wherein the HLR access GUI lists subscribers to a network serviced by the switching center.

89. The GUI of claim 88, wherein the protocol-specific HLR GUIs include one of GSM, CDMA TDMA, AMPS, multiple-protocol and prepaid.

90. The GUI of claim 88, wherein the protocol-specific HLR GUIs comprise a subscriber profile GUI.

91. The GUI of claim 90, wherein the subscriber profile GUI includes:

a subscriber definition window;

a call offering window;

a protocol window;

a call restriction window;

a call feature window;

a line identification window; and

an add, modify, delete window that allows a subscriber's profile to be updated.

92. The GUI of claim 86, wherein the VLR GUI hierarchy comprises:

a password GUI;

a VLR access GUI; and

protocol-specific VLR GUIs, wherein the VLR access GUI lists subscribers active on a network serviced by the switching center.

93. The GUI of claim 82, wherein the protocol-specific VLR GUIs include one of GSM, CDMA, TDMA, AMPS, multiple-protocol and prepaid.

94. The GUI of claim 92, wherein the protocol-specific VLR GUIs comprise a subscriber profile GUI.

95. The GUI of claim 94, wherein the subscriber profile GUI includes:

a subscriber definition window;

a call offering window;

a protocol window;

a call restriction window;

a call feature window;

a line identification window;

a call feature window; and

an add, modify, delete window that allows a subscriber profile to be updated.

96. the GUI of claim 86, wherein the system configuration GUI hierarchy, comprises:

a trunk maintenance GUI, the trunk maintenance GUI including:

a span and channel selection, and

a change channel state selection.

97. The GUI of claim 86, wherein the system configuration GUI hierarchy, comprises:

a board configuration including a modify module that allows a board to be reconfigured.

98. The GUI of claim 97, wherein the board includes one of a T-1/E-1 board, a voice I/O board, a conference board and a SS-7 board.

99. The GUI of claim 86, wherein the call record GUI includes an archived data window.

100. The GUI of claim 86, wherein the call record GUI includes an output selection GUI, the output selection GUI providing one of a display selection, a printer selection, no selection and other output selection.

101. The GUI of claim 86, wherein the call record GUI includes an auto-removal GUI, the auto-removal GUI including a number of days before removing archived files selection.

102. The GUI of claim 87, wherein the rate plan hierarchy GUI, comprises:

a rating administration tab, the rating administration tab displaying a list of distributors;

a distributor data GUI;

a modify distributor data GUI; and

a modify rate plan GUI.

103. The GUI of claim 102, wherein the rate plan hierarchy GUI further comprises a modify prepaid entry GUI.

104. The GUI of claim 103, wherein the prepaid entry GUI, comprises:

a balance window;
a rate information window;
a payment method window; and
an other features window.

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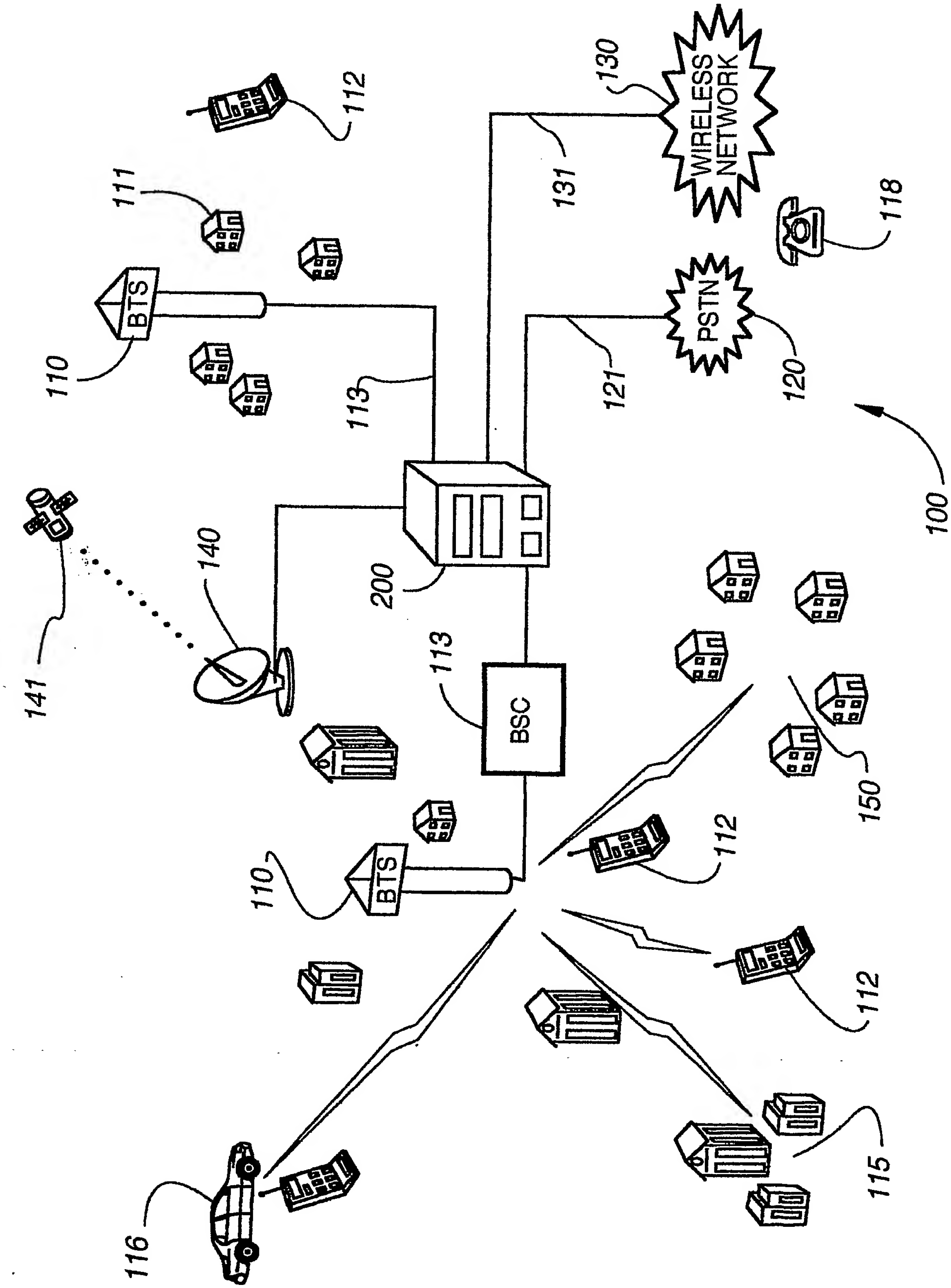

WIRELESS NETWORK
130
131
PSTN
120
121
118
112
111
BTS
110
113
200
140
141
BSC
113
150
100
112
BTS
110
112
115
116

Fig. 1a

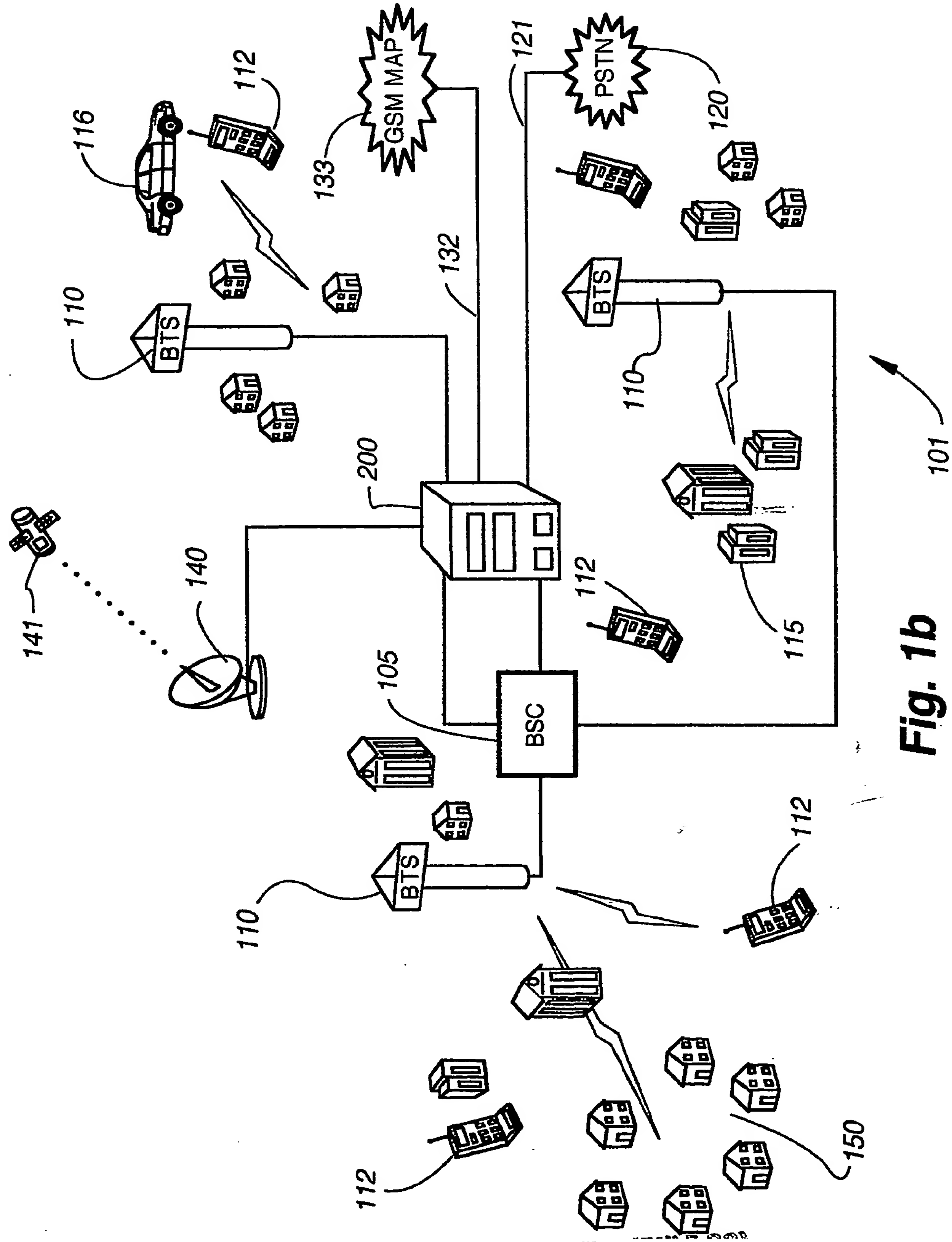
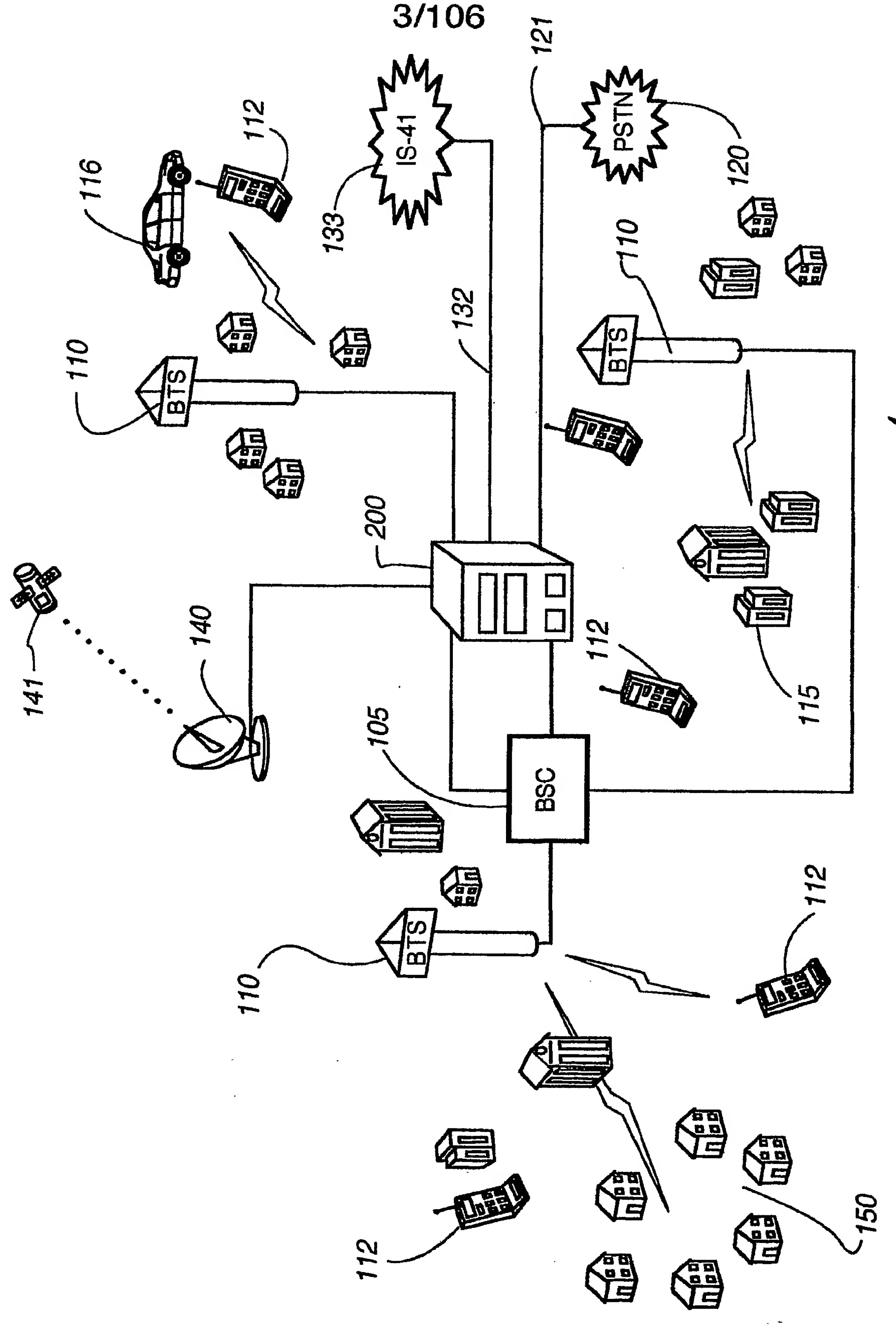

GSM MAP
PSTN
BTS
BTS
BTS
BSC
116
112
133
121
120
132
110
110
110
200
141
140
112
115
105
112
112
150
101

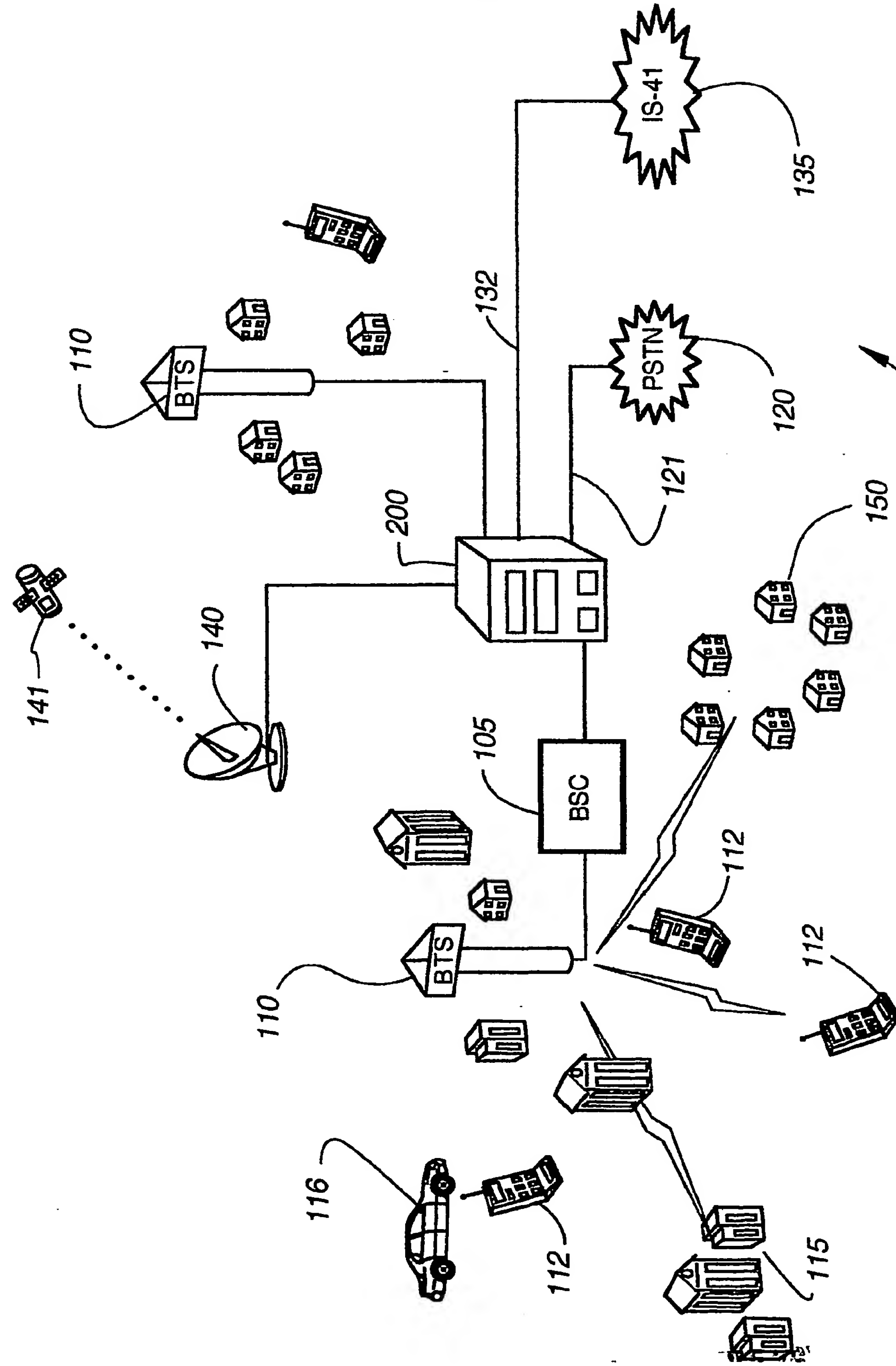
Fig. 1b

3/106



IS-41
PSTN
BTS
BTS
BTS
BSC
101
105
110
110
110
112
112
112
112
112
115
116
120
121
132
133
140
141
150
200

Fig. 1c


IS-41
135
132
PSTN
120
121
103
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BTS
200
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140
105
BSC
112
112
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116
112
115

Fig. 1d

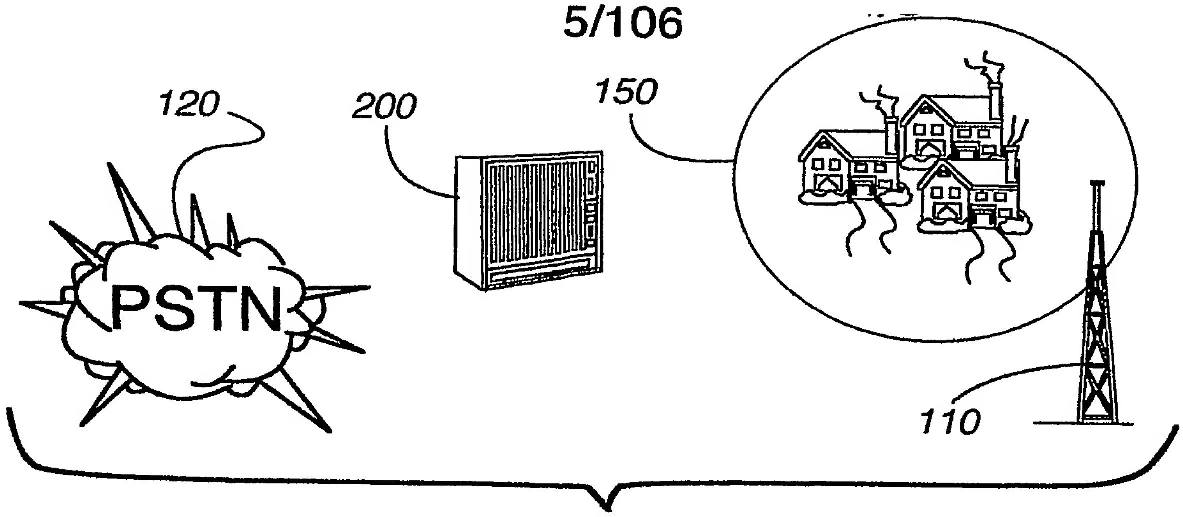

120
200
150
PSTN
110

Fig. 3

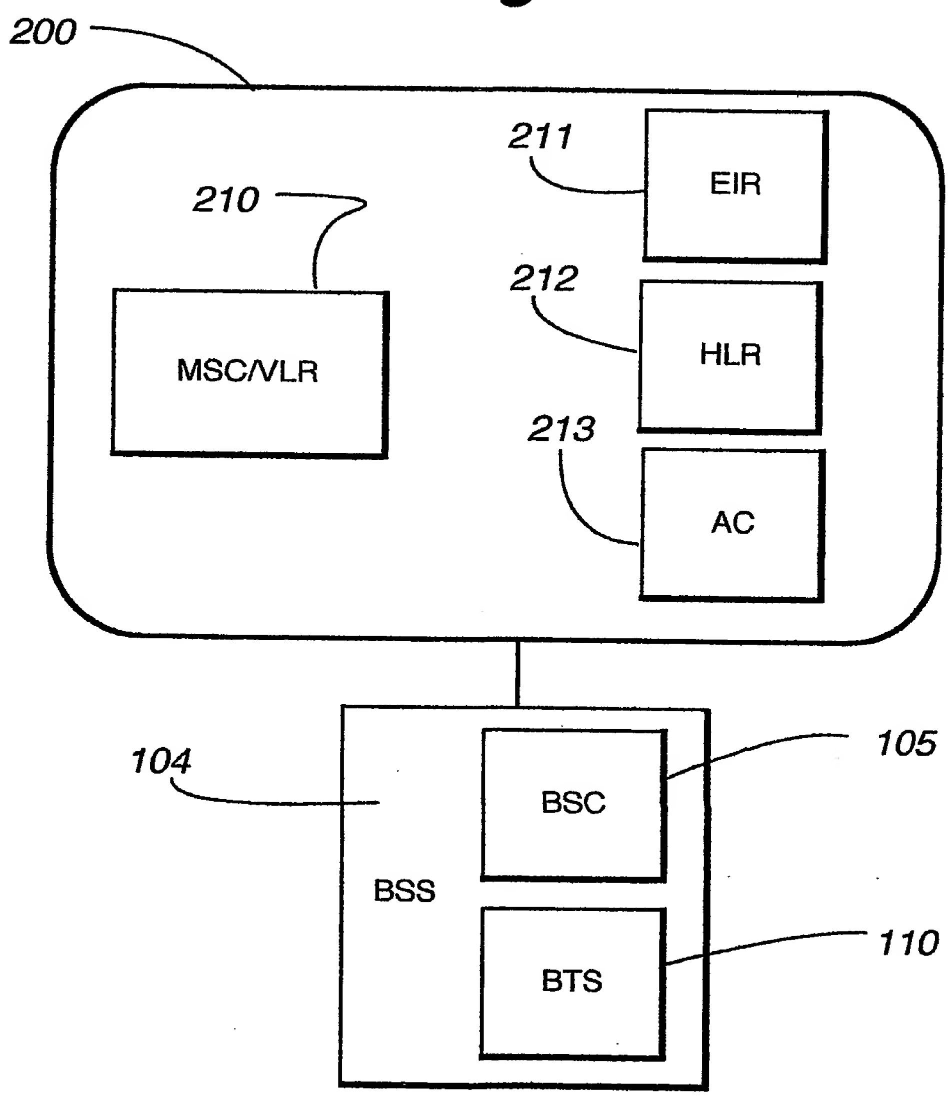

200
211
EIR
210
212
HLR
MSC/VLR
213
AC
104
105
BSC
BSS
110
BTS

Fig. 2

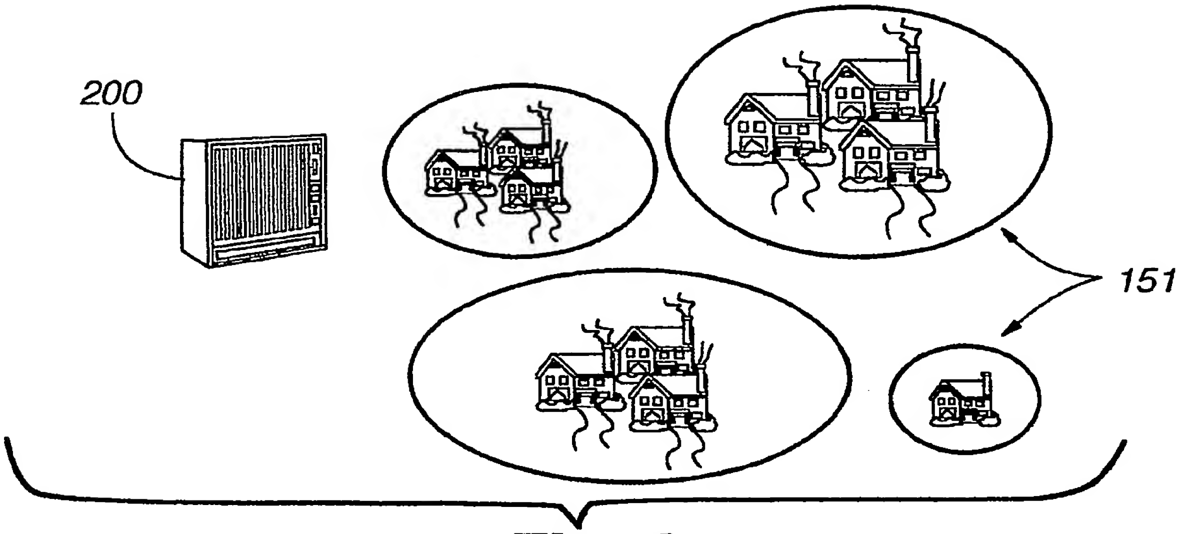


Fig. 4

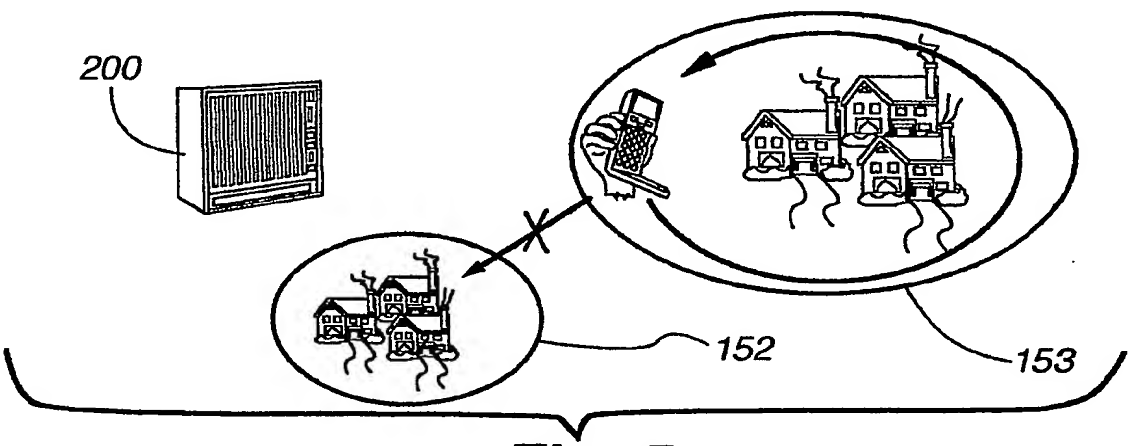


Fig. 5

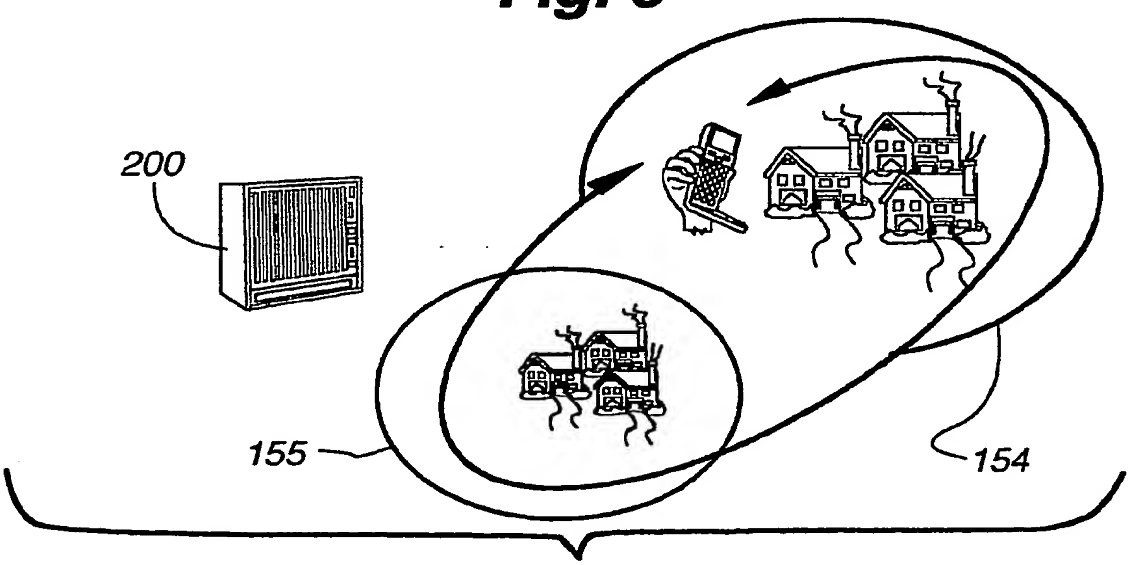


Fig. 6

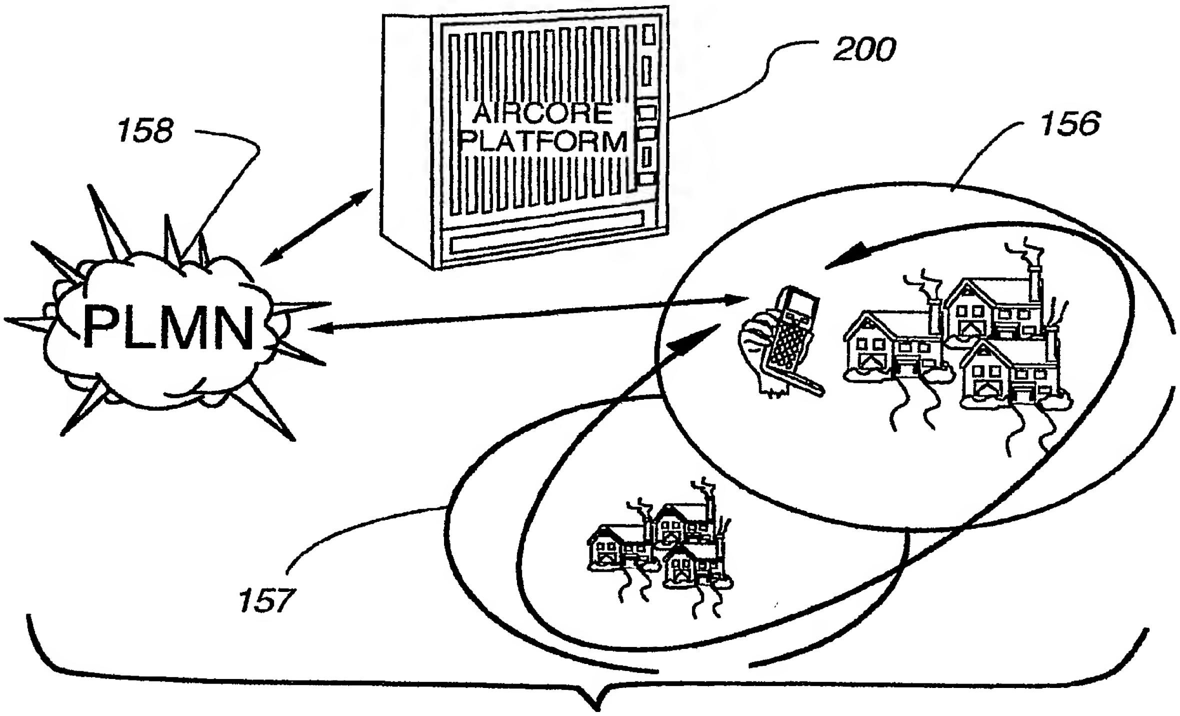

200
AIRCORE PLATFORM
158
156
PLMN
157

Fig. 7

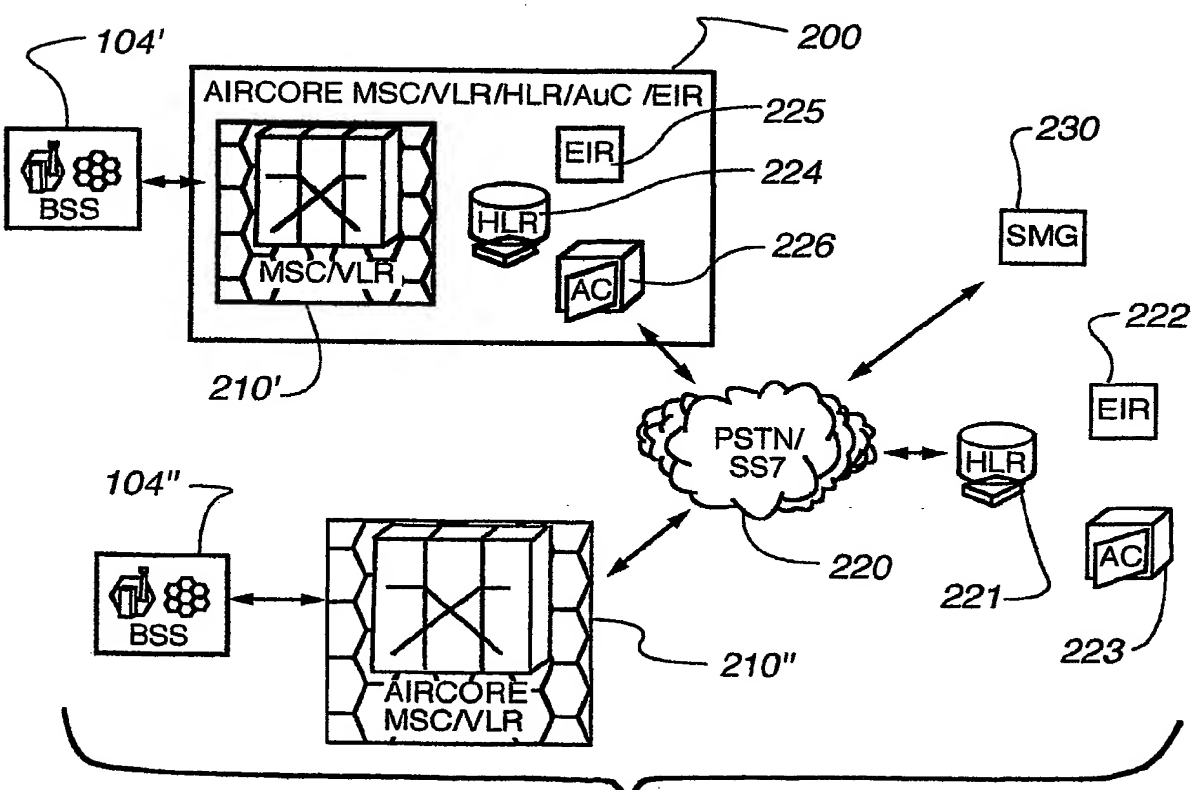
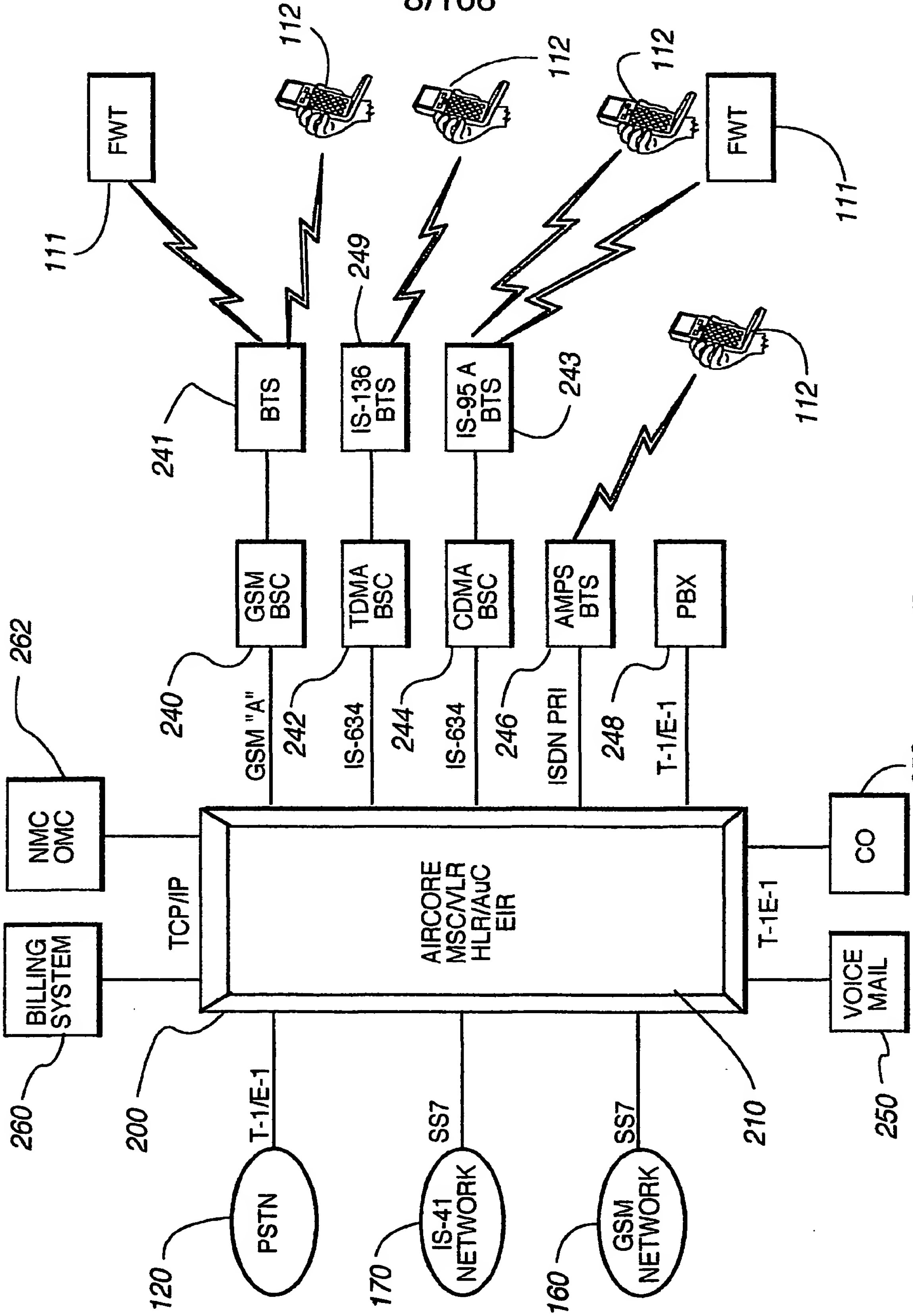

104'
200
AIRCORE MSC/VLR/HLR/AuC /EIR
225
EIR
224
HLR
BSS
MSC/VLR
226
AC
230
SMG
210'
222
EIR
PSTN/
SS7
HLR
104"
BSS
220
221
AC
223
210"
AIRCORE
MSC/VLR

Fig. 8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112
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241
BTS
IS-136 BTS
IS-95 A BTS
243
GSM BSC
TDMA BSC
CDMA BSC
AMPS BTS
PBX
240
242
244
246
248
GSM "A"
IS-634
IS-634
ISDN PRI
T-1/E-1
262
NMC OMC
BILLING SYSTEM
TCP/IP
AIRCORE MSC/VLR HLR/AuC EIR
T-1E-1
CO
252
VOICE MAIL
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260
200
210
T-1/E-1
SS7
SS7
PSTN
IS-41 NETWORK
GSM NETWORK
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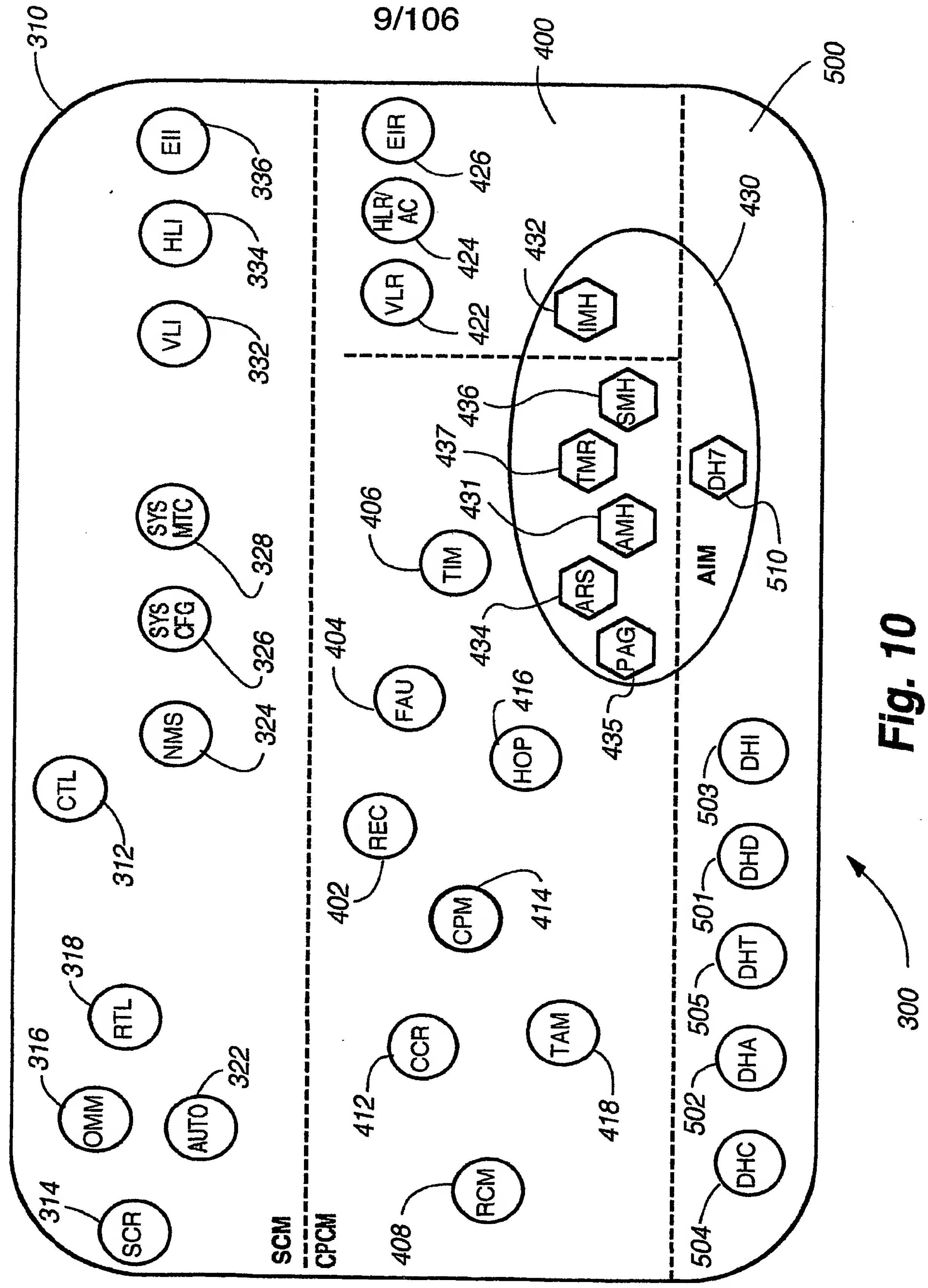
170
160

Fig. 9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AIM
SCR
OMM
AUTO
RTL
CTL
NMS
SYS CFG
SYS MTC
VLI
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RCM
CCR
TAM
CPM
REC
HOP
FAU
TIM
VLR
HLR/AC
EIR
IMH
SMH
TMR
AMH
ARS
PAG
DH7
DHC
DHA
DHT
DHD
DHI
314
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503
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Fig. 10

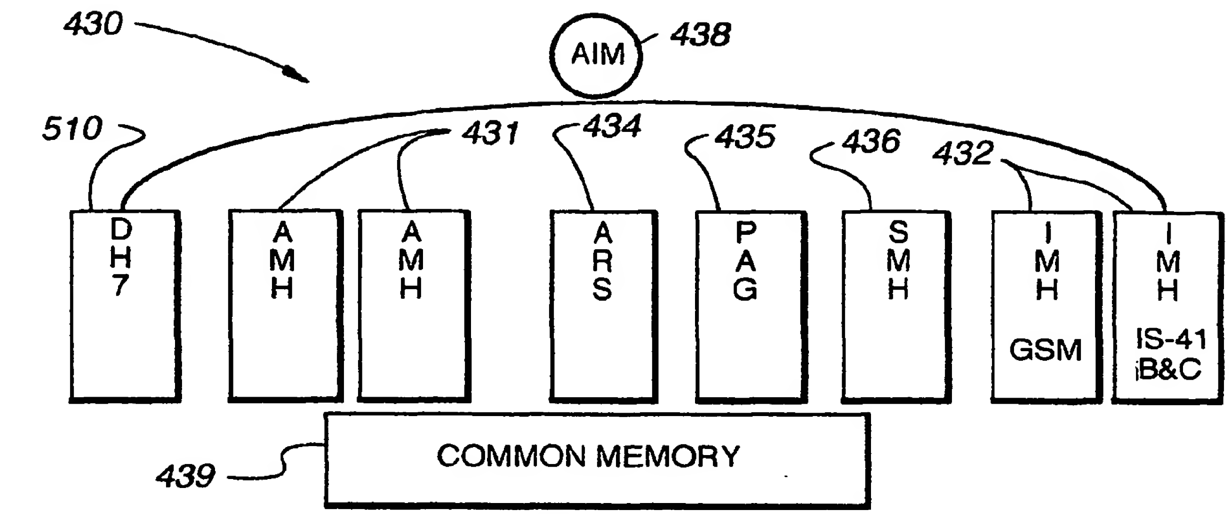


Fig. 11

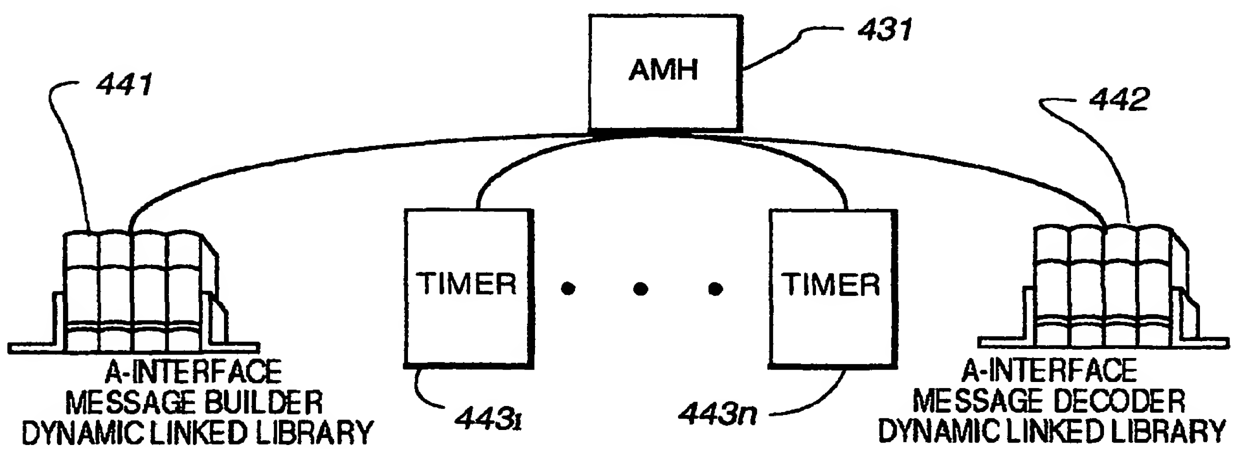


Fig. 12

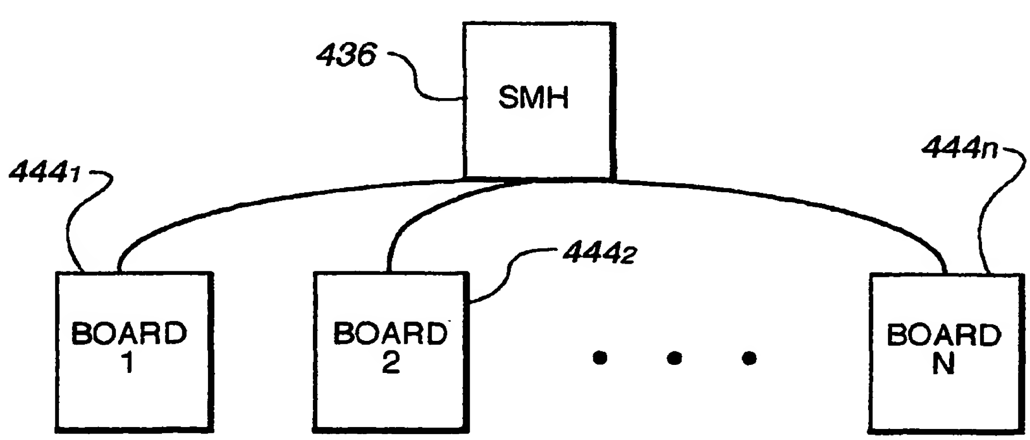


Fig. 13

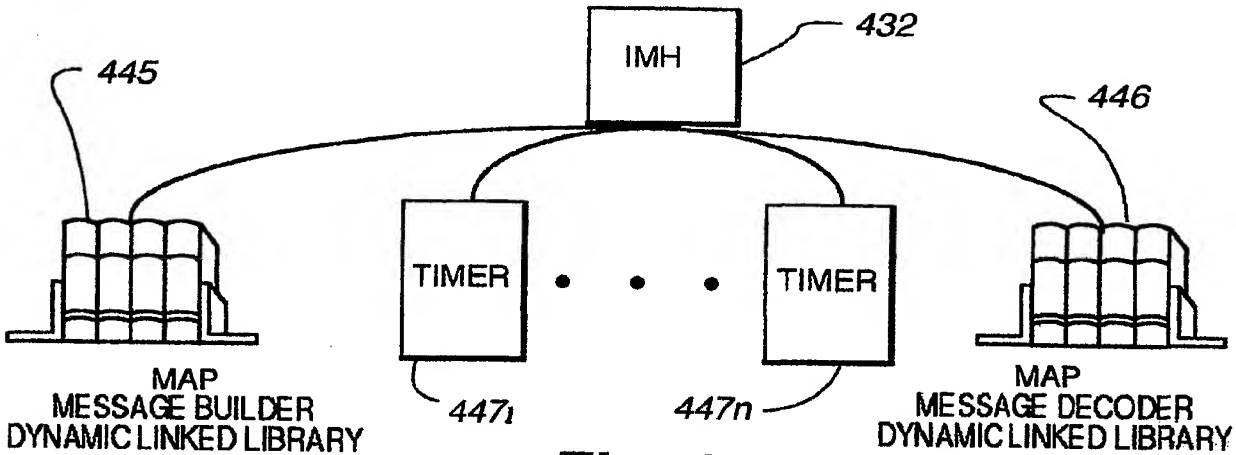


Fig. 14

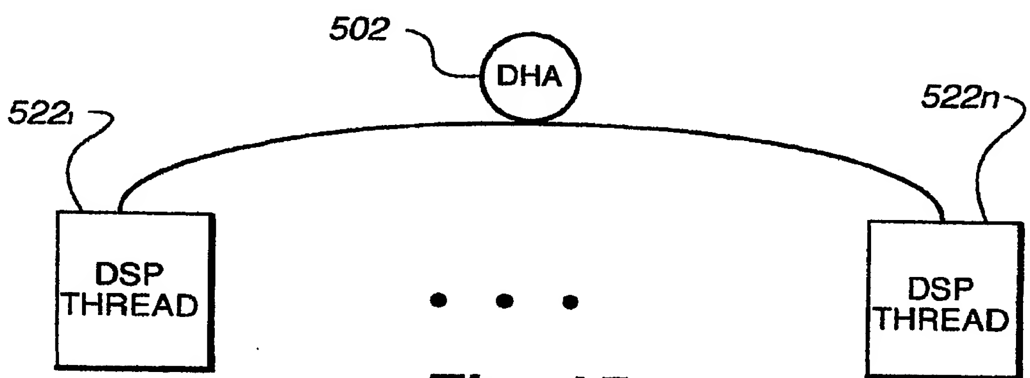


Fig. 15

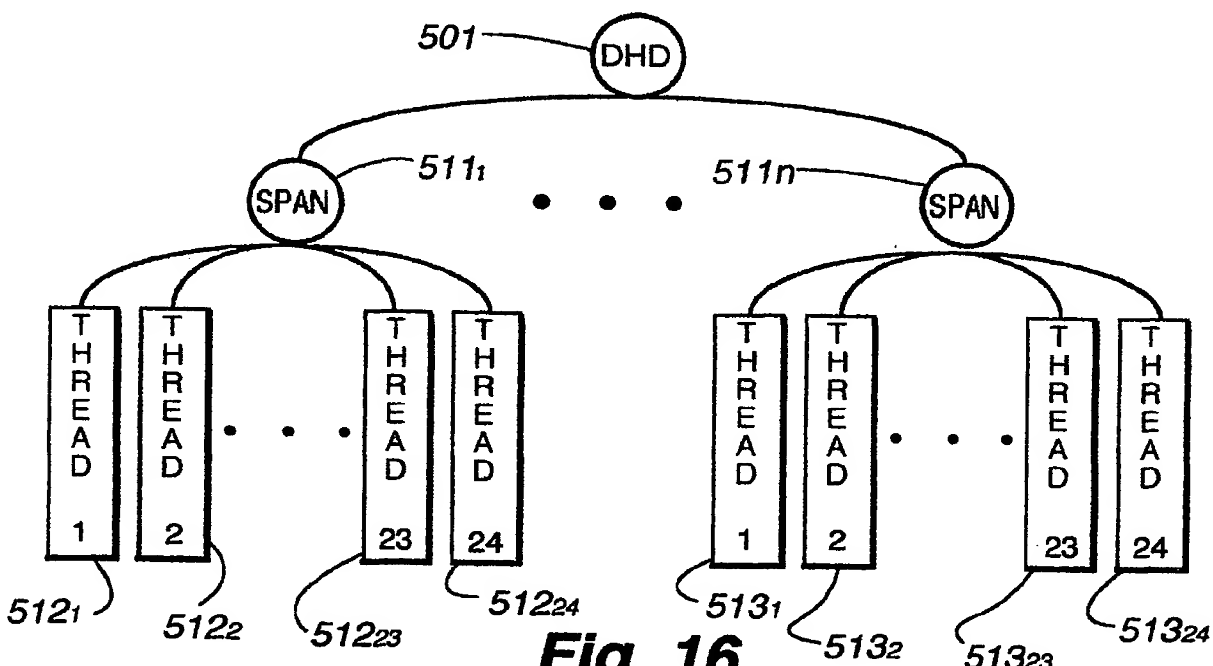


Fig. 16

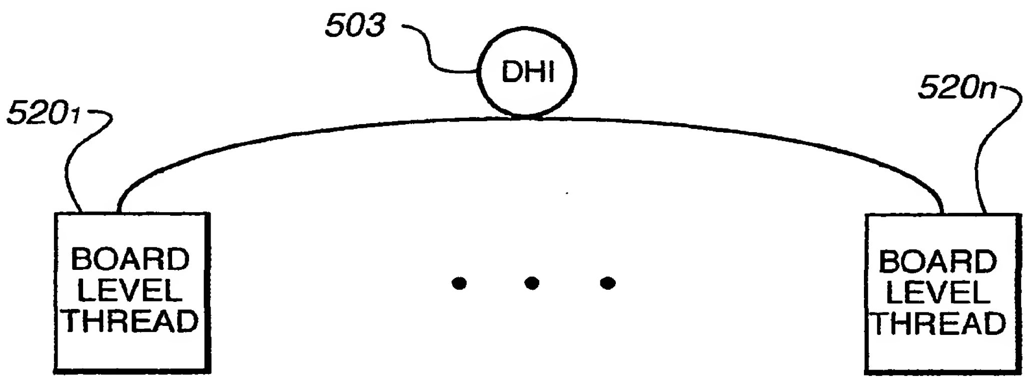


Fig. 17

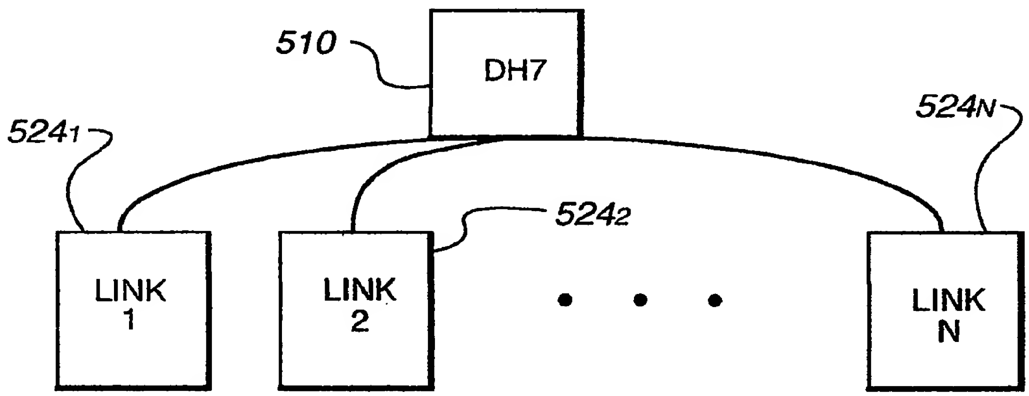


Fig. 18

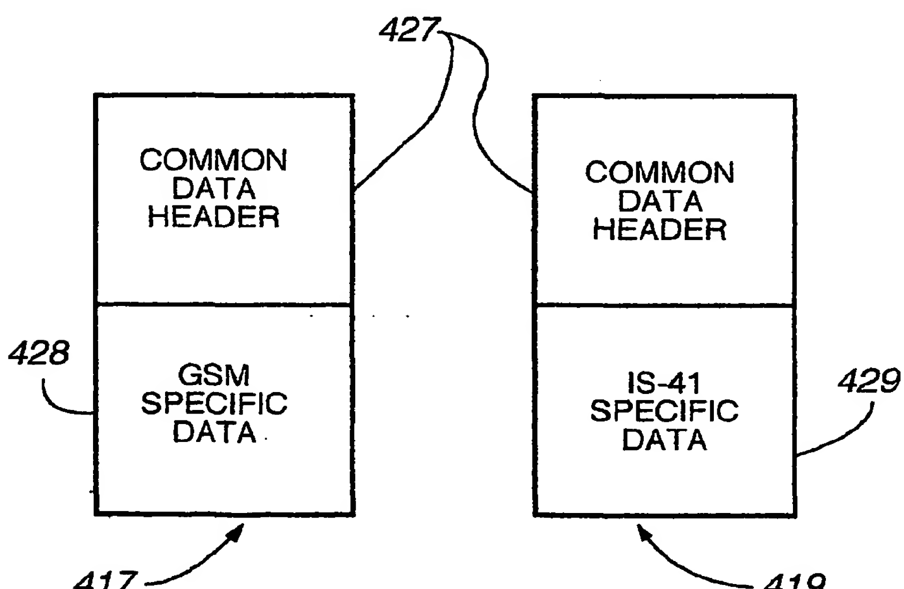
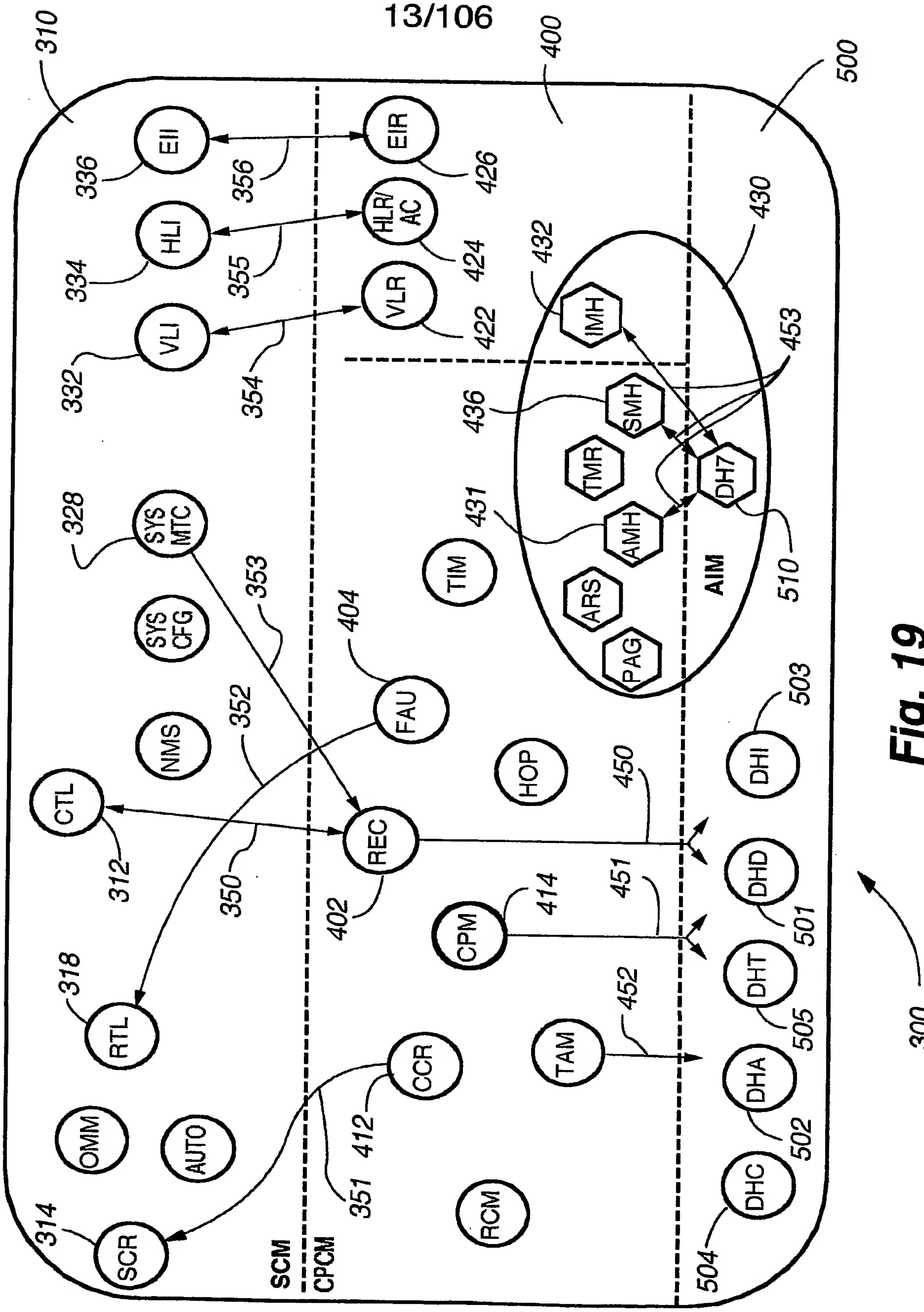


Fig. 21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400
500
SCM
CPCM
AIM
EII
EIR
HLI
HLR/AC
VLI
VLR
SYS MTC
SYS CFG
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CTL
RTL
OMM
AUTO
SCR
CCR
REC
FAU
TIM
HOP
CPM
TAM
RCM
IMH
SMH
TMR
DH7
AMH
ARS
PAG
DHI
DHD
DHT
DHA
DHC
336
356
426
334
355
424
430
432
332
354
422
453
436
431
510
328
353
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314
504
300

Fig. 19

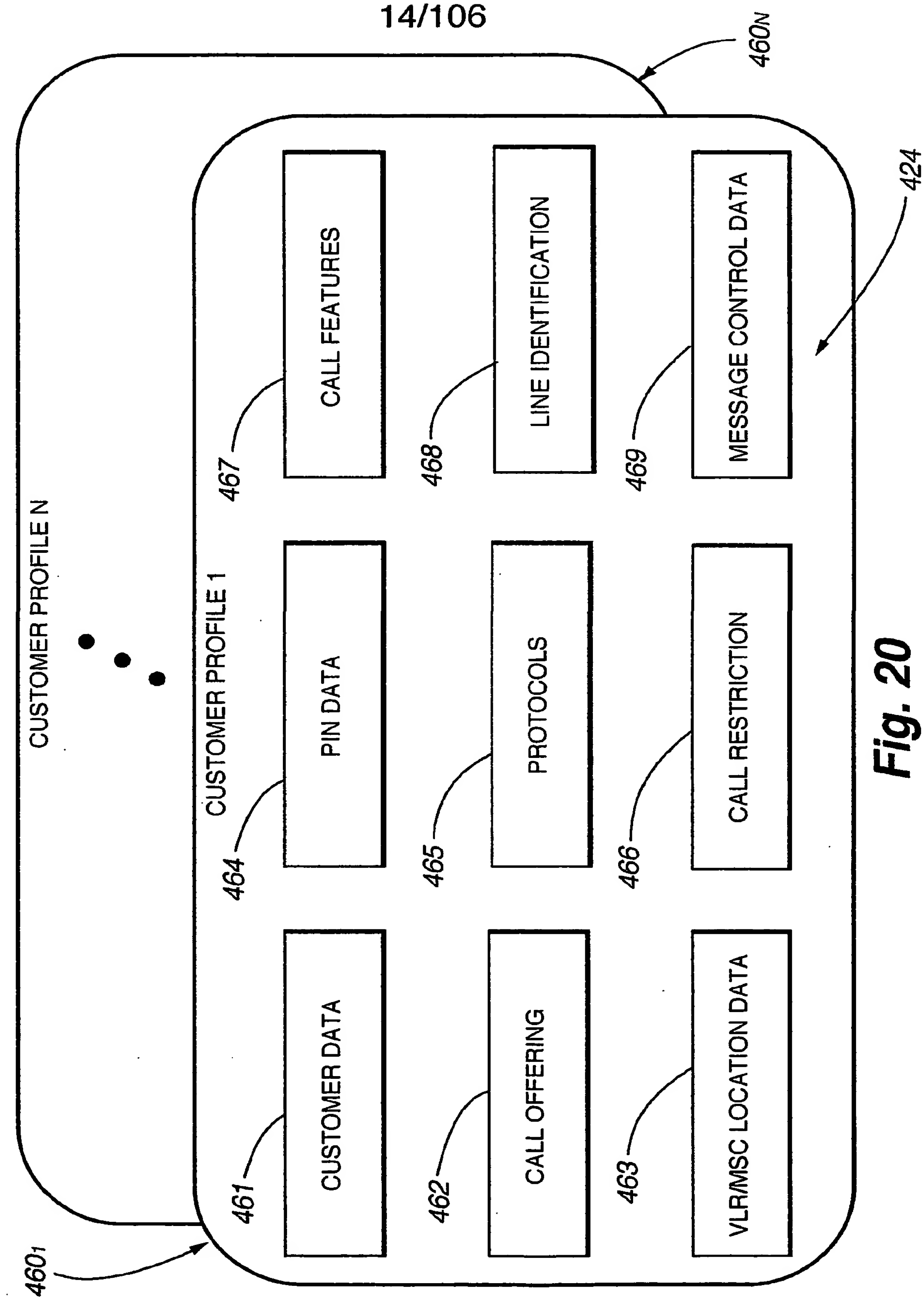

460N
CUSTOMER PROFILE N
CUSTOMER PROFILE 1
424
CALL FEATURES
467
LINE IDENTIFICATION
468
MESSAGE CONTROL DATA
469
PIN DATA
464
PROTOCOLS
465
CALL RESTRICTION
466
CUSTOMER DATA
461
CALL OFFERING
462
VLR/MSC LOCATION DATA
463
460₁

Fig. 20

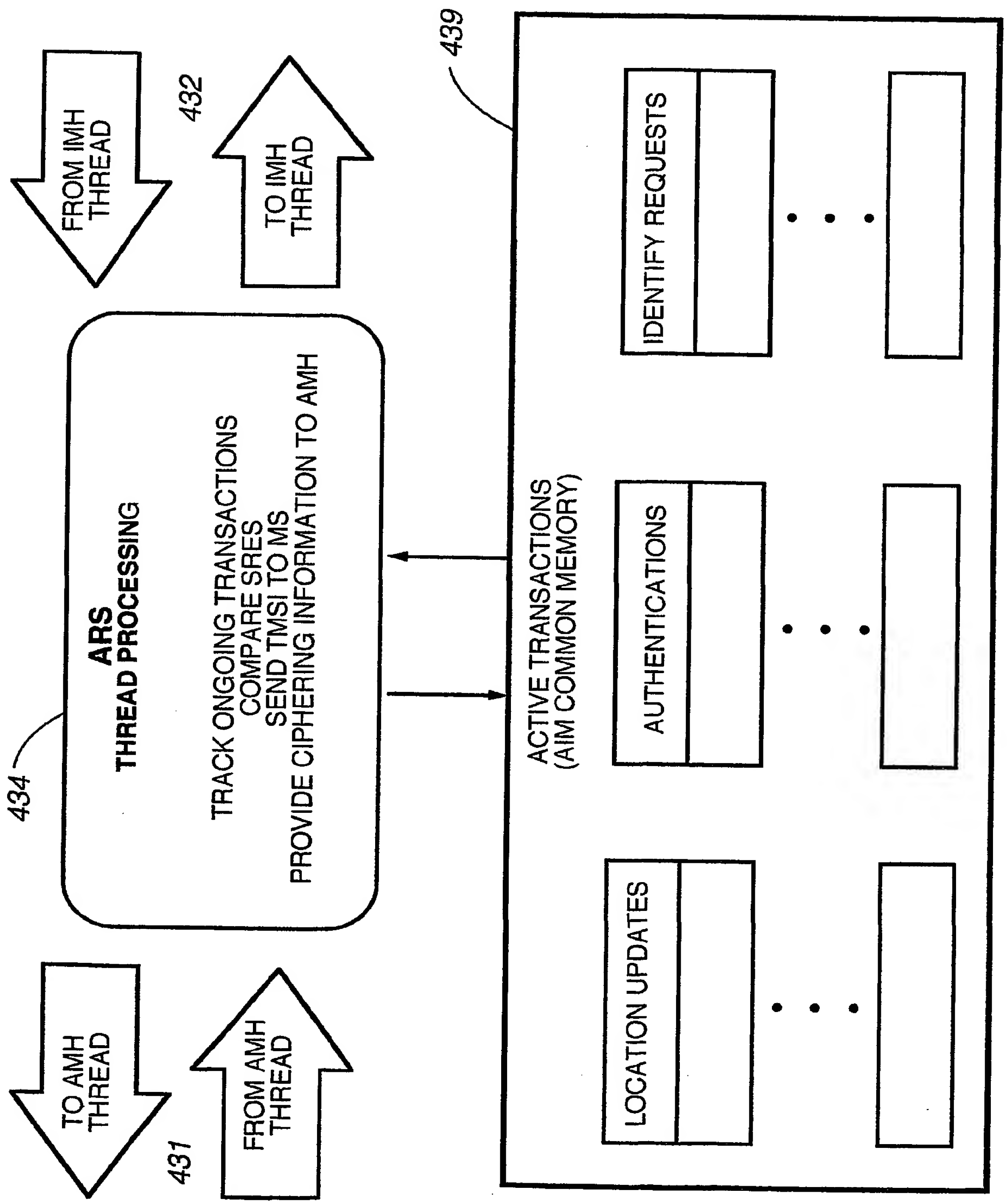

FROM IMH THREAD
432
TO IMH THREAD
439
434
ARS
THREAD PROCESSING
TRACK ONGOING TRANSACTIONS
COMPARE SRES
SEND TMSI TO MS
PROVIDE CIPHERING INFORMATION TO AMH
TO AMH THREAD
FROM AMH THREAD
431
ACTIVE TRANSACTIONS
(AIM COMMON MEMORY)
IDENTIFY REQUESTS
AUTHENTICATIONS
LOCATION UPDATES

Fig. 22

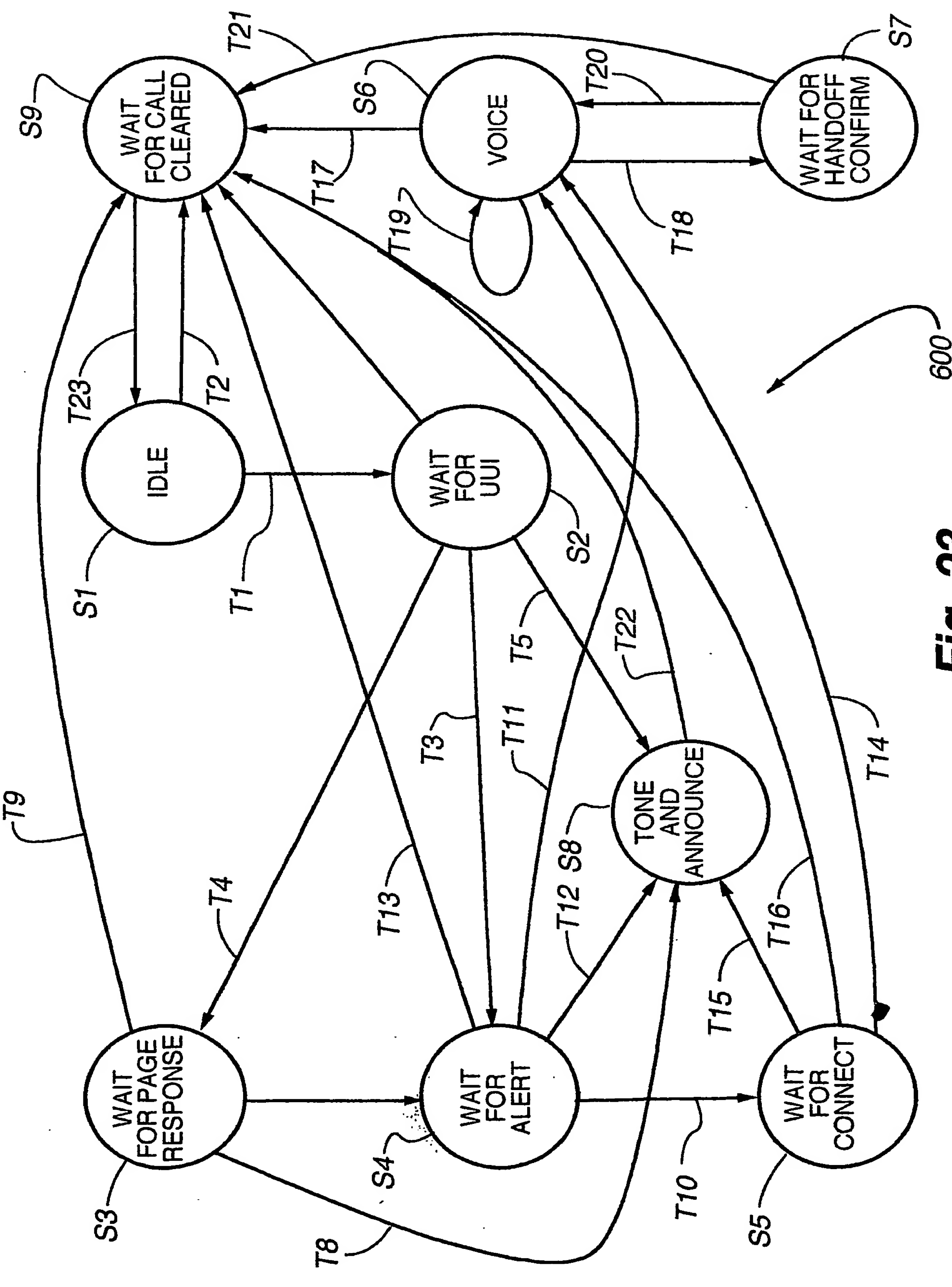

WAIT FOR CALL CLEARED
VOICE
WAIT FOR HANDOFF CONFIRM
IDLE
WAIT FOR UUI
TONE AND ANNOUNCE
WAIT FOR PAGE RESPONSE
WAIT FOR ALERT
WAIT FOR CONNECT
S1
S2
S3
S4
S5
S6
S7
S8
S9
T1
T2
T3
T4
T5
T8
T9
T10
T11
T12
T13
T14
T15
T16
T17
T18
T19
T20
T21
T22
T23
600

Fig. 23

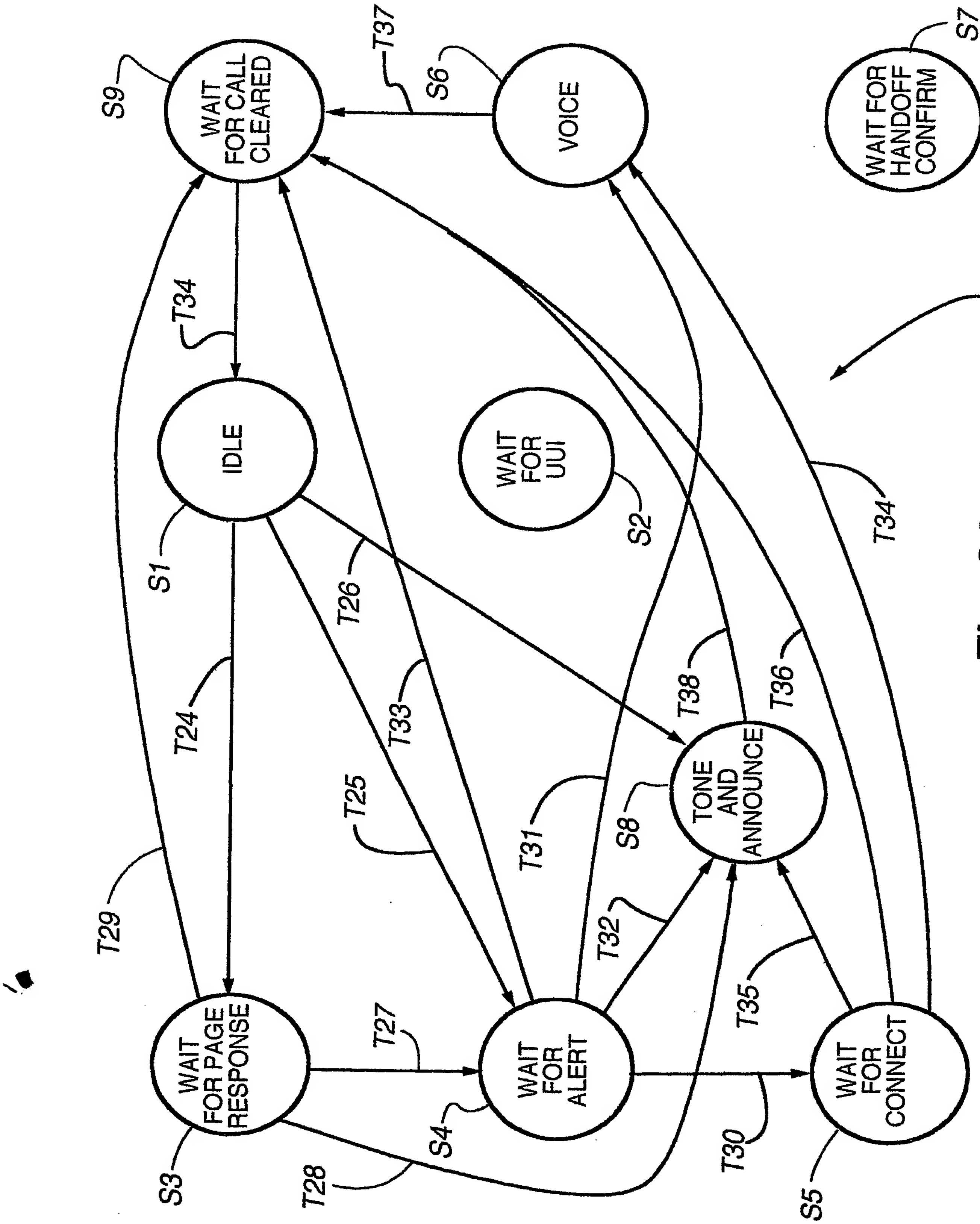

WAIT FOR CALL CLEARED
S9
VOICE
S6
T37
WAIT FOR HANDOFF CONFIRM
S7
IDLE
S1
T34
WAIT FOR UUI
S2
601
TONE AND ANNOUNCE
S8
T38
T36
T34
T24
T26
T33
T25
T31
T29
T32
T35
WAIT FOR PAGE RESPONSE
S3
T27
WAIT FOR ALERT
S4
T28
T30
WAIT FOR CONNECT
S5

Fig. 24

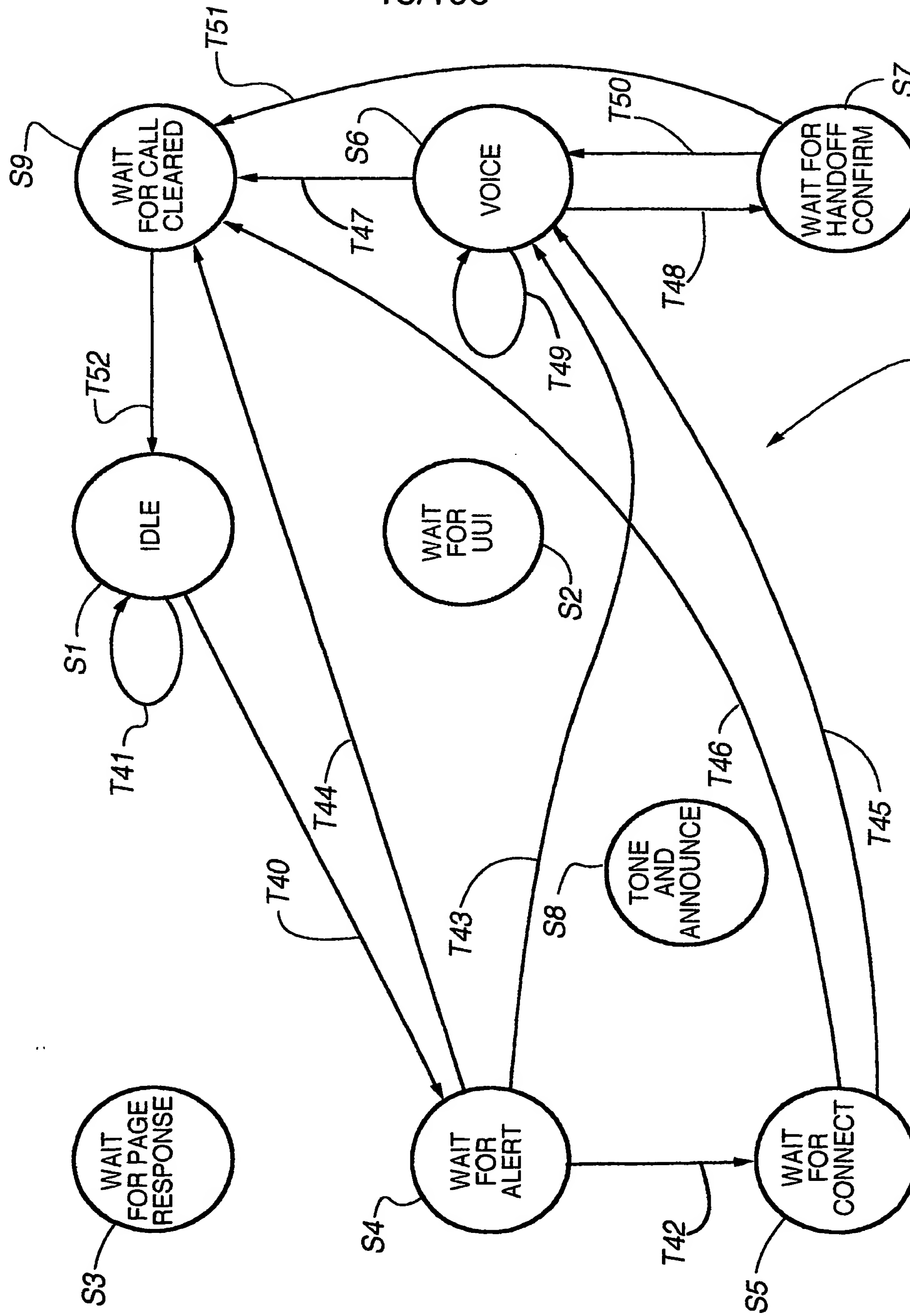

WAIT FOR CALL CLEARED
S9
VOICE
S6
WAIT FOR HANDOFF CONFIRM
S7
T51
T50
T47
T48
T49
T52
IDLE
S1
T41
WAIT FOR UUI
S2
601
T44
T40
T43
T46
T45
TONE AND ANNOUNCE
S8
WAIT FOR PAGE RESPONSE
S3
WAIT FOR ALERT
S4
WAIT FOR CONNECT
S5
T42

Fig. 25

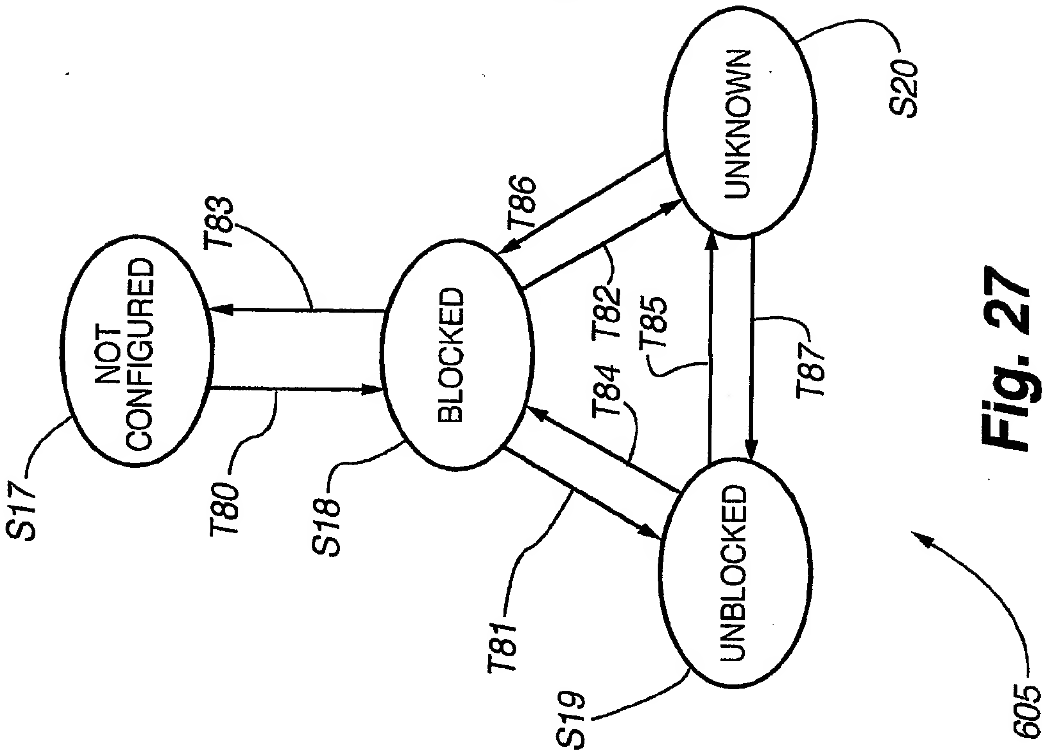

NOT CONFIGURED
BLOCKED
UNBLOCKED
UNKNOWN
S17
S18
S19
S20
T80
T81
T82
T83
T84
T85
T86
T87
605

Fig. 27

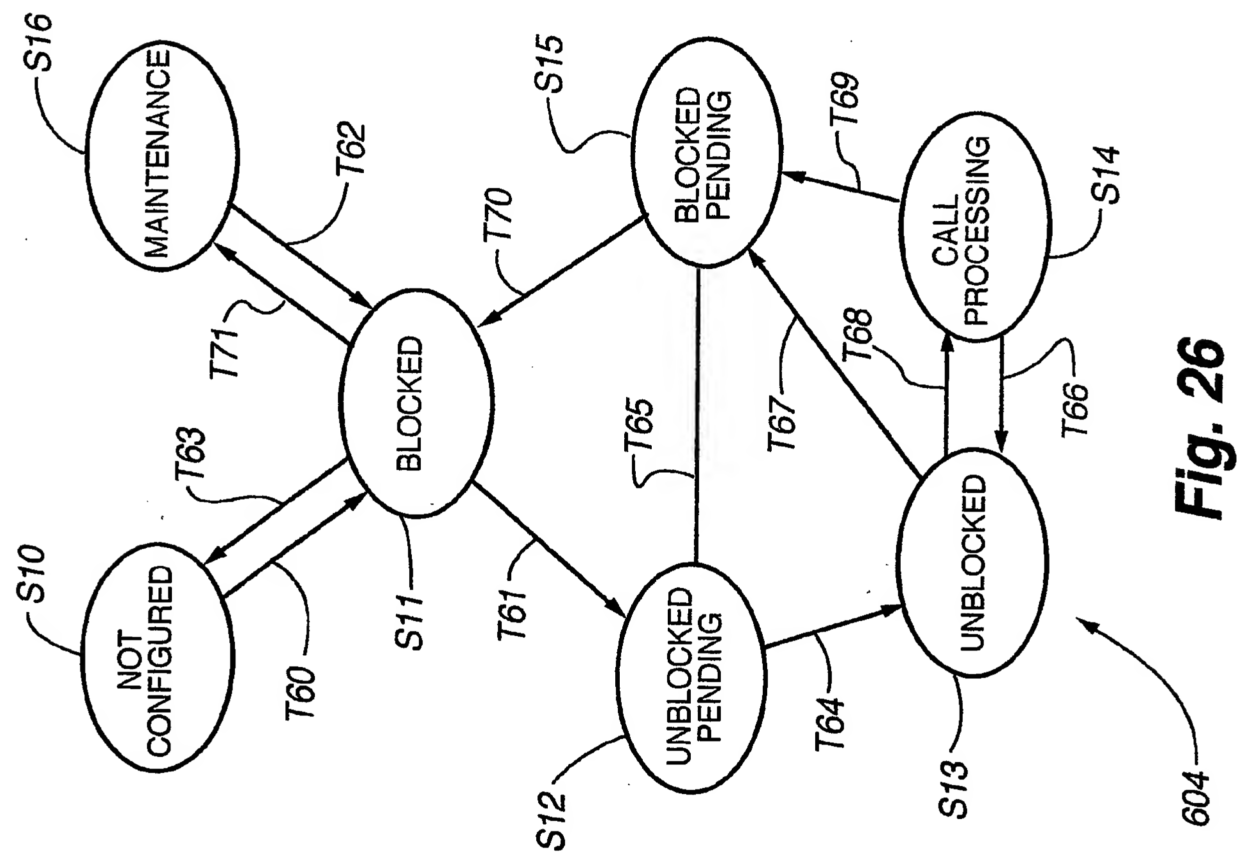

NOT CONFIGURED
MAINTENANCE
BLOCKED
BLOCKED PENDING
UNBLOCKED PENDING
UNBLOCKED
CALL PROCESSING
S10
S11
S12
S13
S14
S15
S16
T60
T61
T62
T63
T64
T65
T66
T67
T68
T69
T70
T71
604

Fig. 26

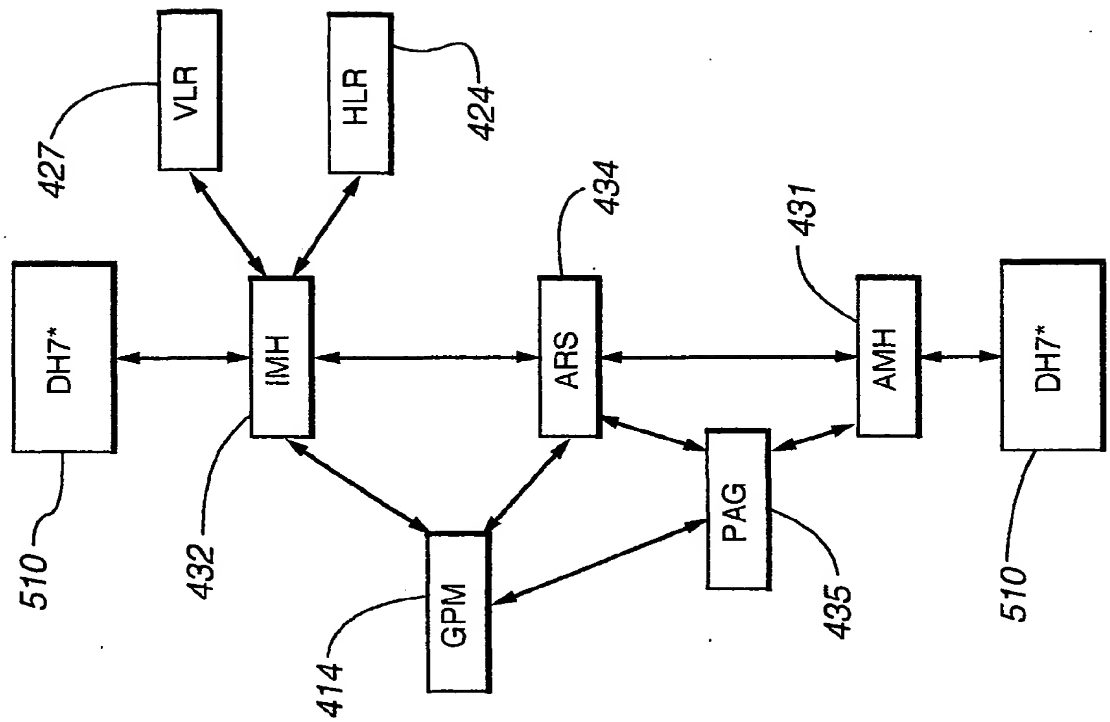


Fig. 29a

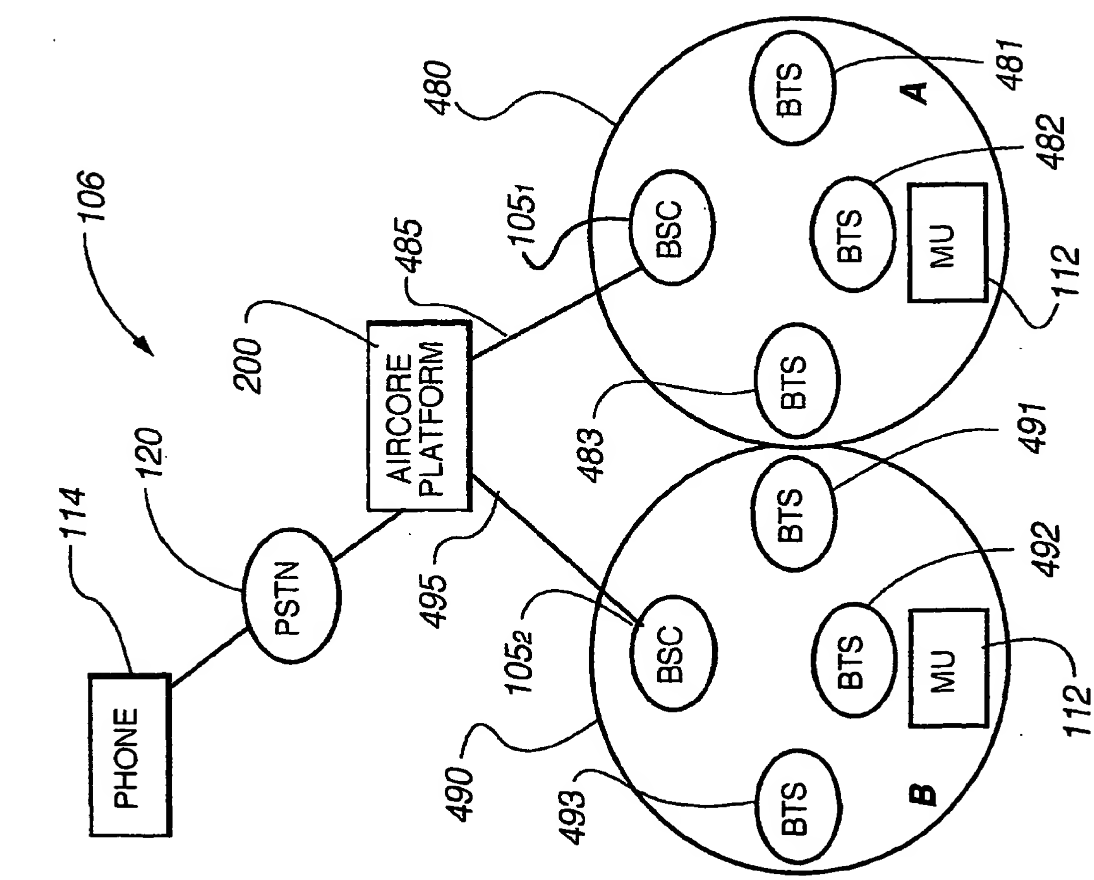


Fig. 28

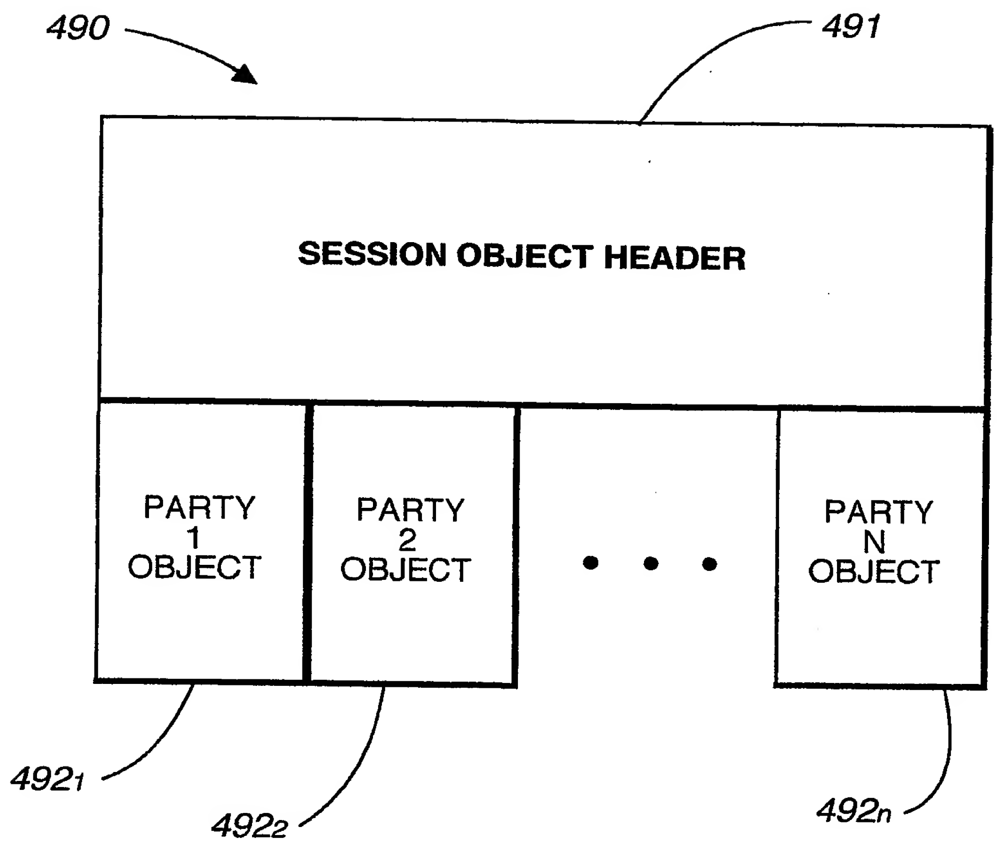

490
491
SESSION OBJECT HEADER
PARTY 1 OBJECT
PARTY 2 OBJECT
PARTY N OBJECT
492₁
492₂
492n

Fig. 29b

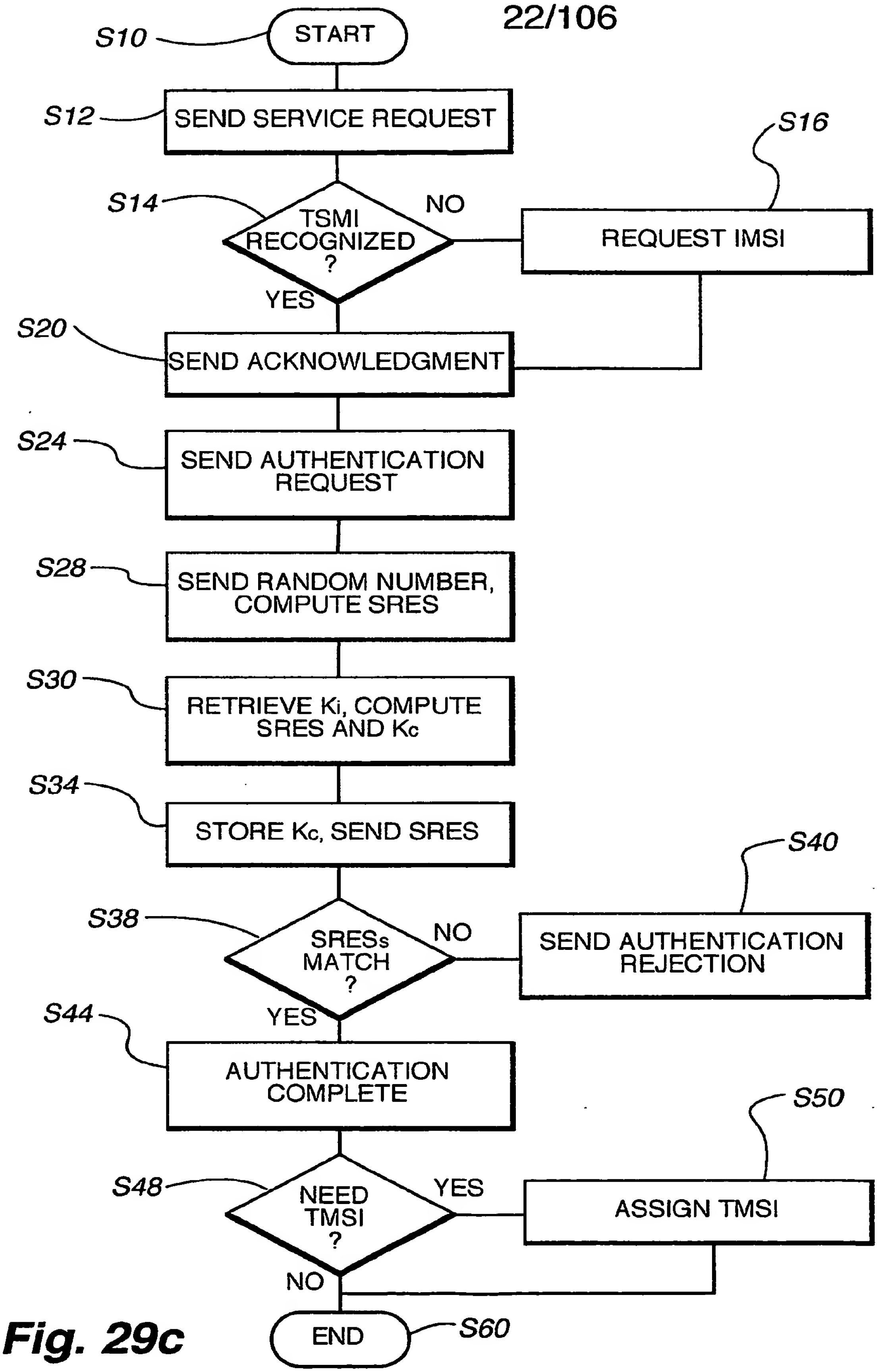
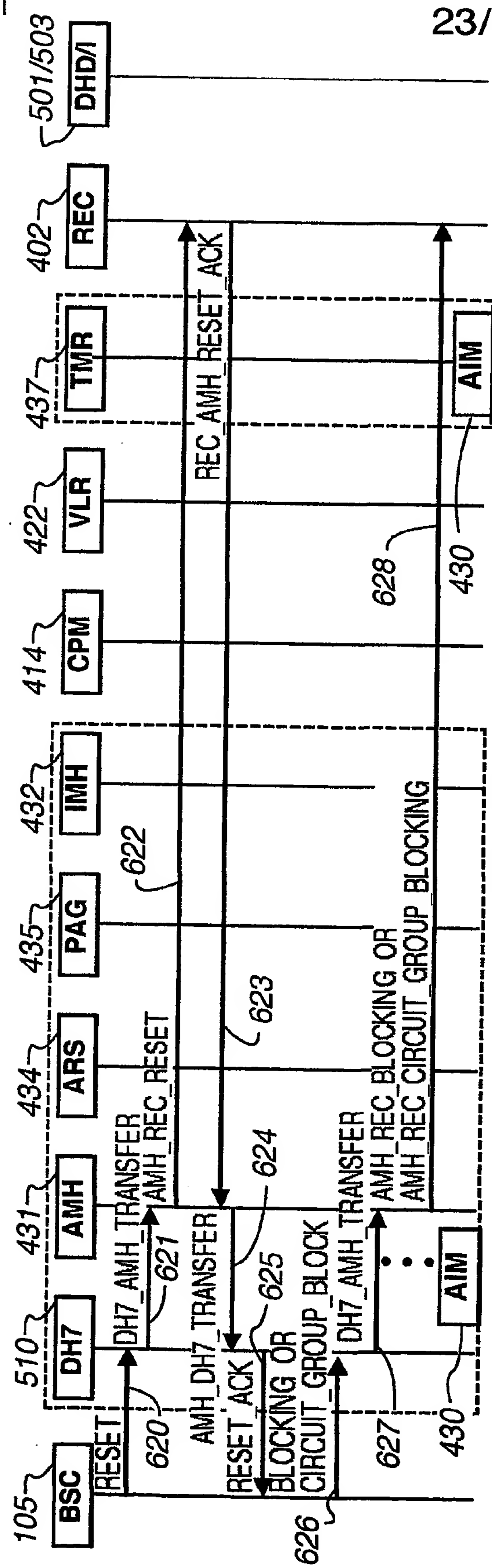
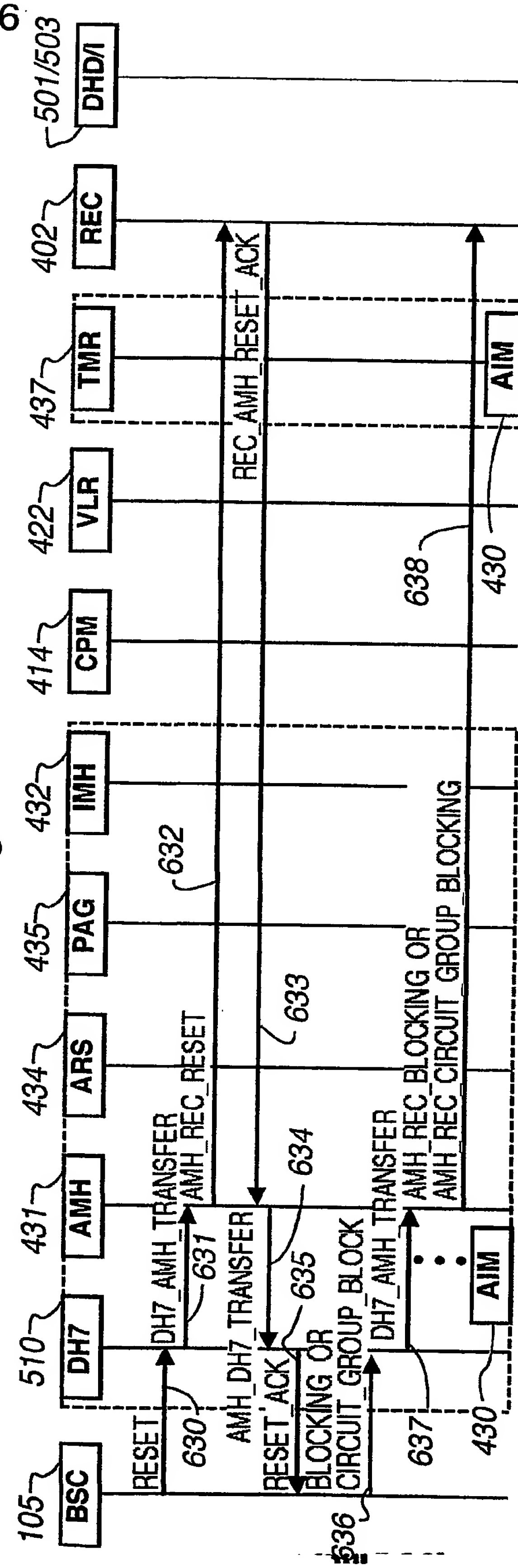

S10
START
S12
SEND SERVICE REQUEST
S14
TSMI RECOGNIZED ?
NO
YES
S16
REQUEST IMSI
S20
SEND ACKNOWLEDGMENT
S24
SEND AUTHENTICATION REQUEST
S28
SEND RANDOM NUMBER, COMPUTE SRES
S30
RETRIEVE Ki, COMPUTE SRES AND Kc
S34
STORE Kc, SEND SRES
S38
SRESs MATCH ?
NO
YES
S40
SEND AUTHENTICATION REJECTION
S44
AUTHENTICATION COMPLETE
S48
NEED TMSI ?
YES
NO
S50
ASSIGN TMSI
END
S60

Fig. 29c



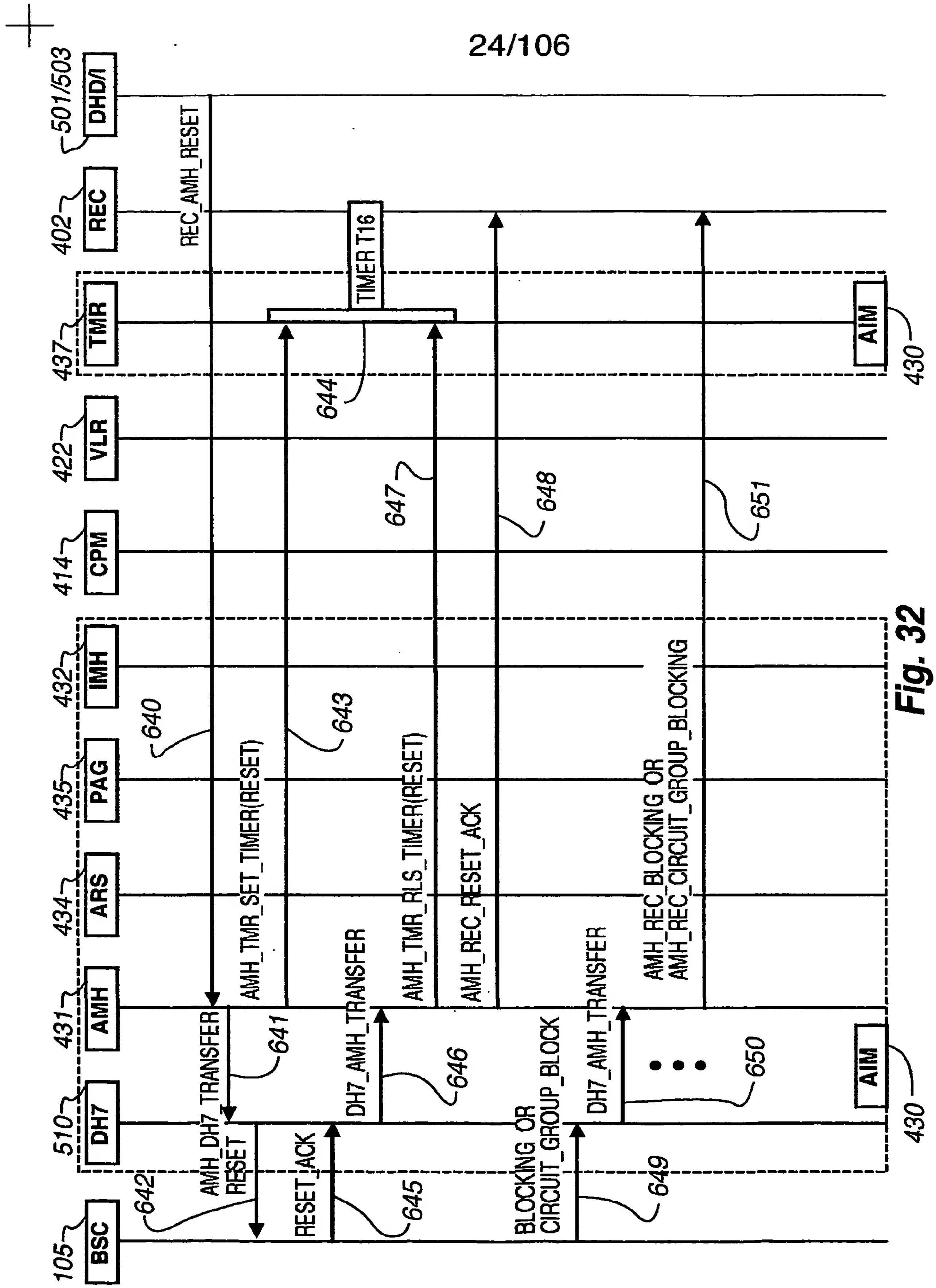
BSC
105
DH7
510
AMH
431
ARS
434
PAG
435
IMH
432
CPM
414
VLR
422
TMR
437
REC
402
DHD/I
501/503
RESET
620
DH7_AMH_TRANSFER
621
AMH_REC_RESET
622
REC_AMH_RESET_ACK
623
AMH_DH7_TRANSFER
624
RESET_ACK
625
BLOCKING OR CIRCUIT_GROUP_BLOCK
626
DH7_AMH_TRANSFER
627
AMH_REC_BLOCKING OR AMH_REC_CIRCUIT_GROUP_BLOCKING
628
AIM
430

Fig. 30



BSC
105
DH7
510
AMH
431
ARS
434
PAG
435
IMH
432
CPM
414
VLR
422
TMR
437
REC
402
DHD/I
501/503
RESET
630
DH7_AMH_TRANSFER
631
AMH_REC_RESET
632
REC_AMH_RESET_ACK
633
AMH_DH7_TRANSFER
634
RESET_ACK
635
BLOCKING OR CIRCUIT_GROUP_BLOCK
636
DH7_AMH_TRANSFER
637
AMH_REC_BLOCKING OR AMH_REC_CIRCUIT_GROUP_BLOCKING
638
AIM
430

Fig. 31



501/503
DHD/I
402
REC
437
TMR
422
VLR
414
CPM
432
IMH
435
PAG
434
ARS
431
AMH
510
DH7
105
BSC
430
AIM
REC_AMH_RESET
TIMER T16
644
647
648
651
640
643
AMH_TMR_SET_TIMER(RESET)
AMH_TMR_RLS_TIMER(RESET)
AMH_REC_RESET_ACK
AMH_REC_BLOCKING OR
AMH_REC_CIRCUIT_GROUP_BLOCKING
AMH_DH7_TRANSFER
641
DH7_AMH_TRANSFER
646
DH7_AMH_TRANSFER
650
AMH_DH7_TRANSFER
RESET
642
RESET_ACK
645
BLOCKING OR
CIRCUIT_GROUP_BLOCK
649

Fig. 32

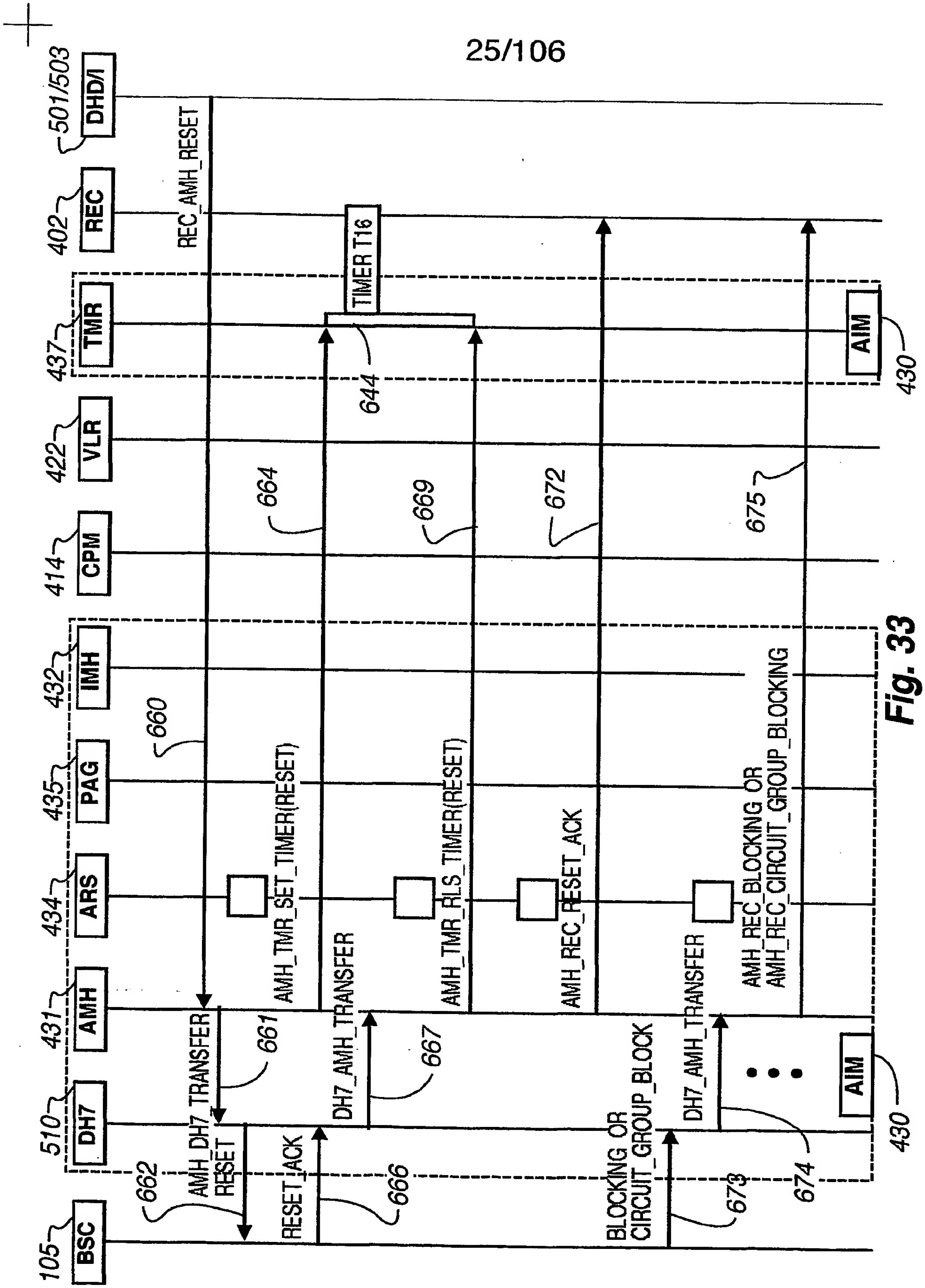
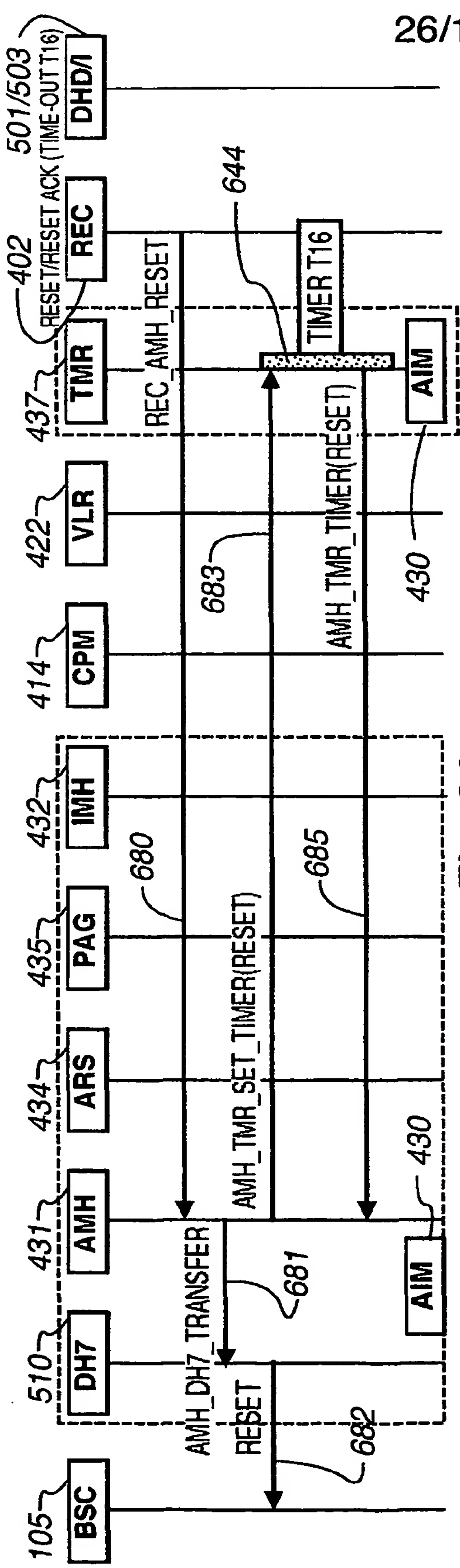
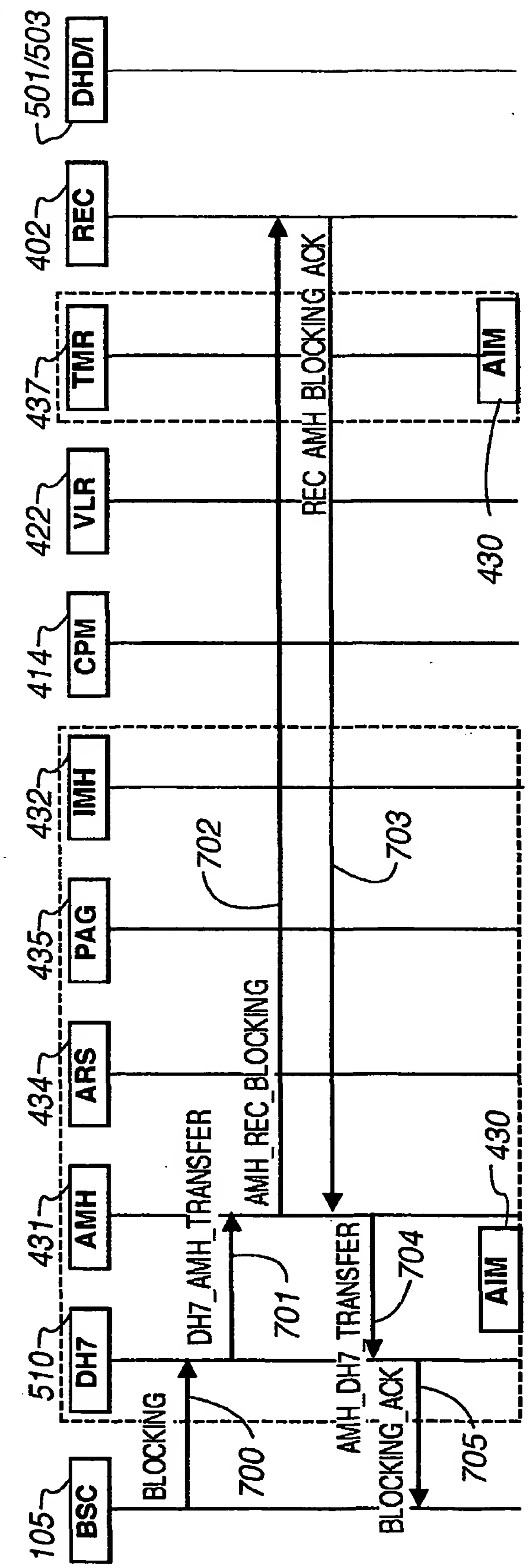

501/503
DHD/I
402
REC
437
TMR
422
VLR
414
CPM
432
IMH
435
PAG
434
ARS
431
AMH
510
DH7
105
BSC
REC_AMH_RESET
TIMER T16
644
AIM
430
664
669
672
675
660
AMH_TMR_SET_TIMER(RESET)
AMH_TMR_RLS_TIMER(RESET)
AMH_REC_RESET_ACK
AMH_REC_BLOCKING OR
AMH_REC_CIRCUIT_GROUP_BLOCKING
AMH_TRANSFER
AMH_TRANSFER
DH7_AMH_TRANSFER
661
DH7_AMH_TRANSFER
667
DH7_AMH_TRANSFER
AMH_DH7_TRANSFER
RESET
662
RESET_ACK
666
BLOCKING OR
CIRCUIT_GROUP_BLOCK
673
674
AIM
430

Fig. 33



105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
402 REC
501/503 DHD/I
RESET/RESET ACK (TIME-OUT T16)
REC_AMH_RESET
680
AMH_DH7_TRANSFER
681
RESET
682
AMH_TMR_SET_TIMER(RESET)
683
644
TIMER T16
AMH_TMR_TIMER(RESET)
685
AIM
430

Fig. 34



105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
402 REC
501/503 DHD/I
BLOCKING
700
DH7_AMH_TRANSFER
701
AMH_REC_BLOCKING
702
REC_AMH_BLOCKING_ACK
703
AMH_DH7_TRANSFER
704
BLOCKING_ACK
705
AIM
430

Fig. 35

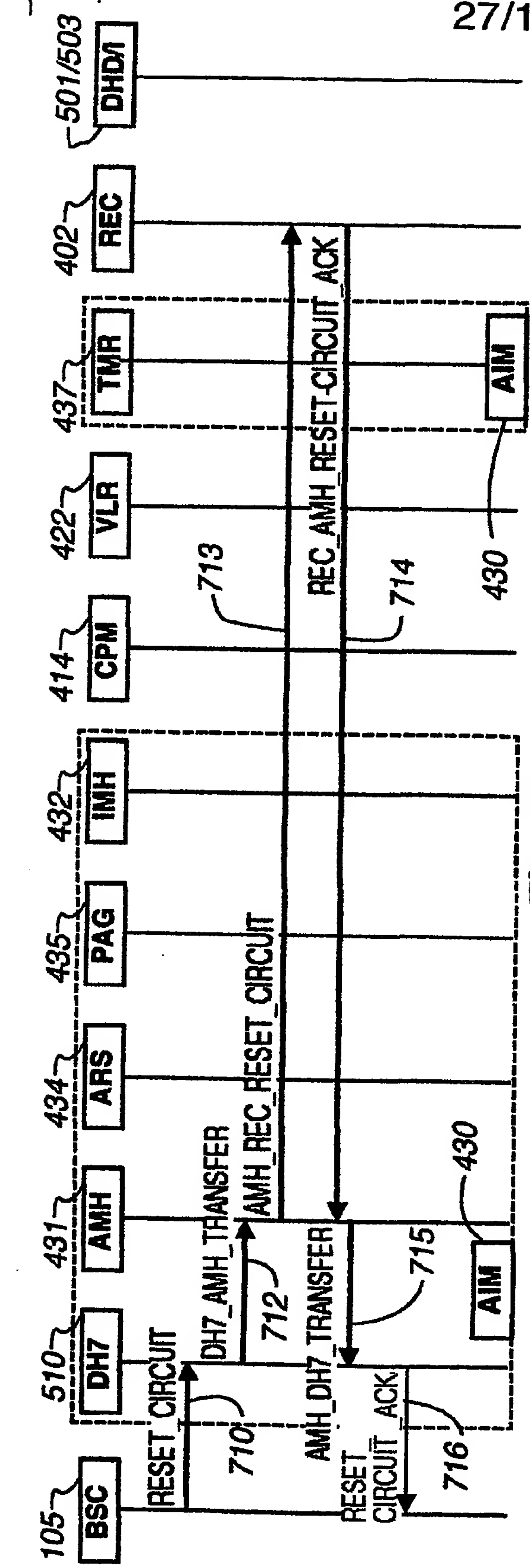

105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
402 REC
501/503 DHD/I
AIM
430
RESET_CIRCUIT
710
DH7_AMH_TRANSFER
712
AMH_REC_RESET_CIRCUIT
713
REC_AMH_RESET-CIRCUIT_ACK
714
AMH_DH7_TRANSFER
715
RESET_CIRCUIT_ACK
716

Fig. 36

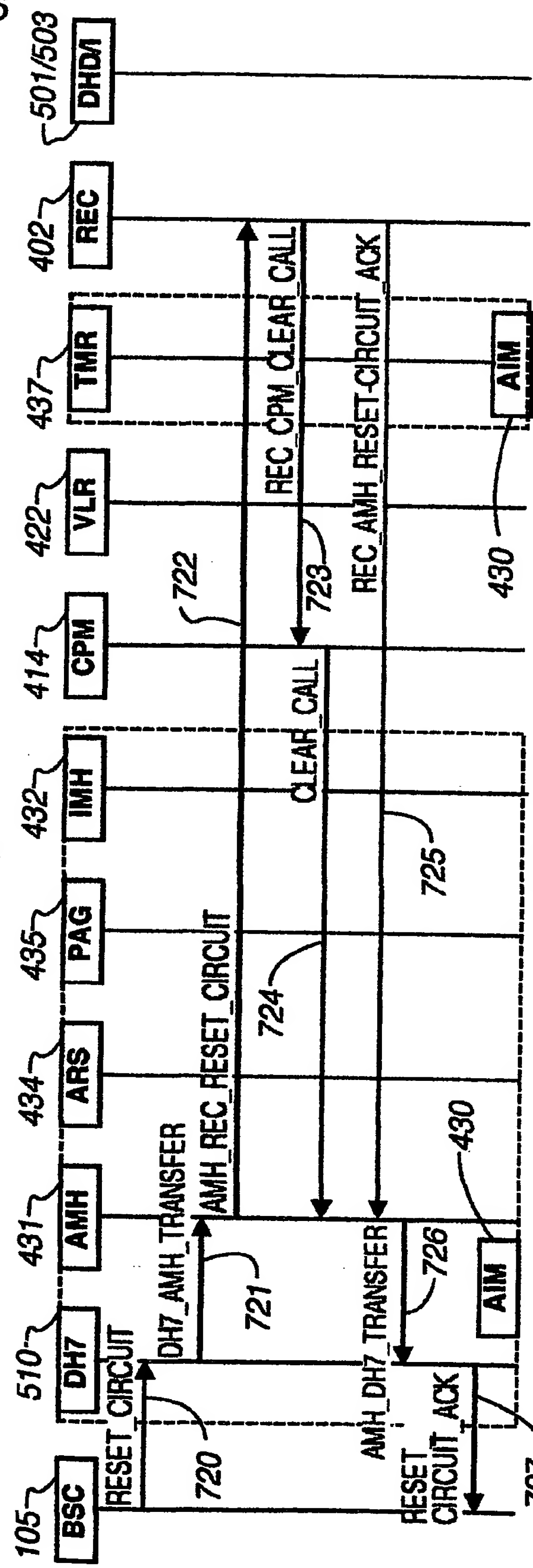

105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
402 REC
501/503 DHD/I
AIM
430
RESET_CIRCUIT
720
DH7_AMH_TRANSFER
721
AMH_REC_RESET_CIRCUIT
722
REC_CPM_CLEAR_CALL
723
CLEAR_CALL
724
REC_AMH_RESET-CIRCUIT_ACK
725
AMH_DH7_TRANSFER
726
RESET_CIRCUIT_ACK
727

Fig. 37

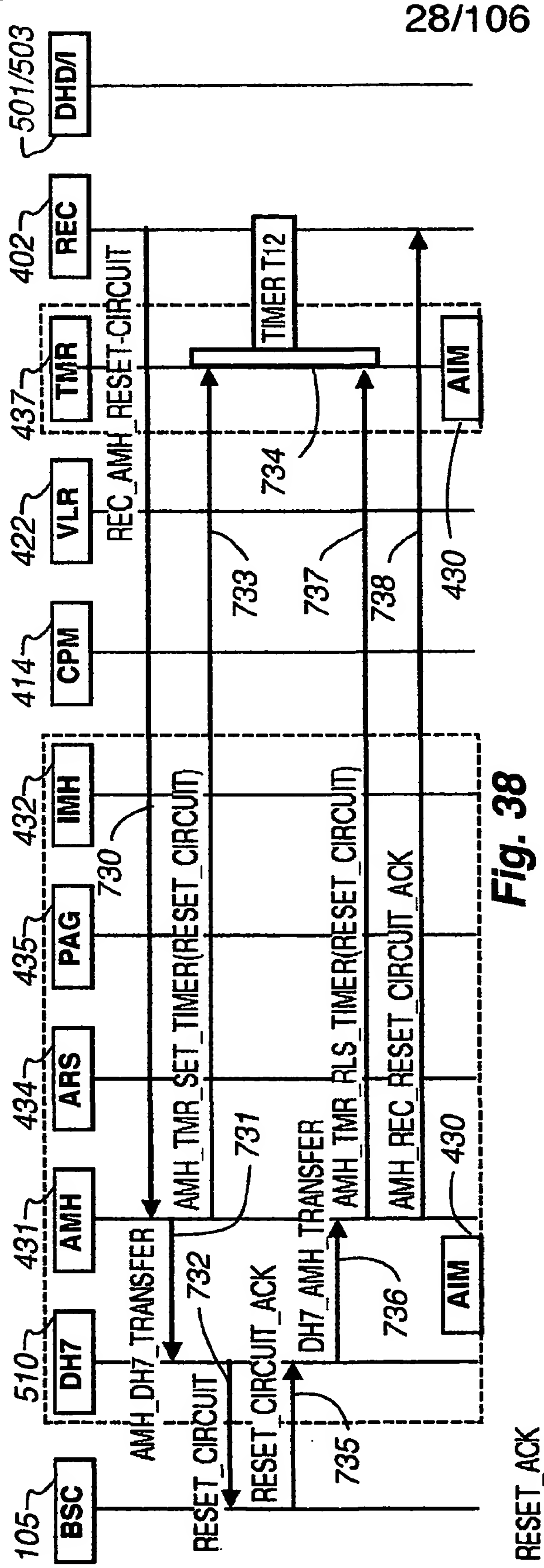

501/503
DHD/I
402
REC
437
TMR
422
VLR
414
CPM
432
IMH
435
PAG
434
ARS
431
AMH
510
DH7
105
BSC
REC_AMH_RESET-CIRCUIT
TIMER T12
AIM
734
733
737
738
430
730
AMH_TMR_SET_TIMER(RESET_CIRCUIT)
731
AMH_TMR_RLS_TIMER(RESET_CIRCUIT)
AMH_REC_RESET_CIRCUIT_ACK
AMH_DH7_TRANSFER
732
RESET_CIRCUIT_ACK
DH7_AMH_TRANSFER
736
RESET_CIRCUIT
735
RESET_ACK

Fig. 38

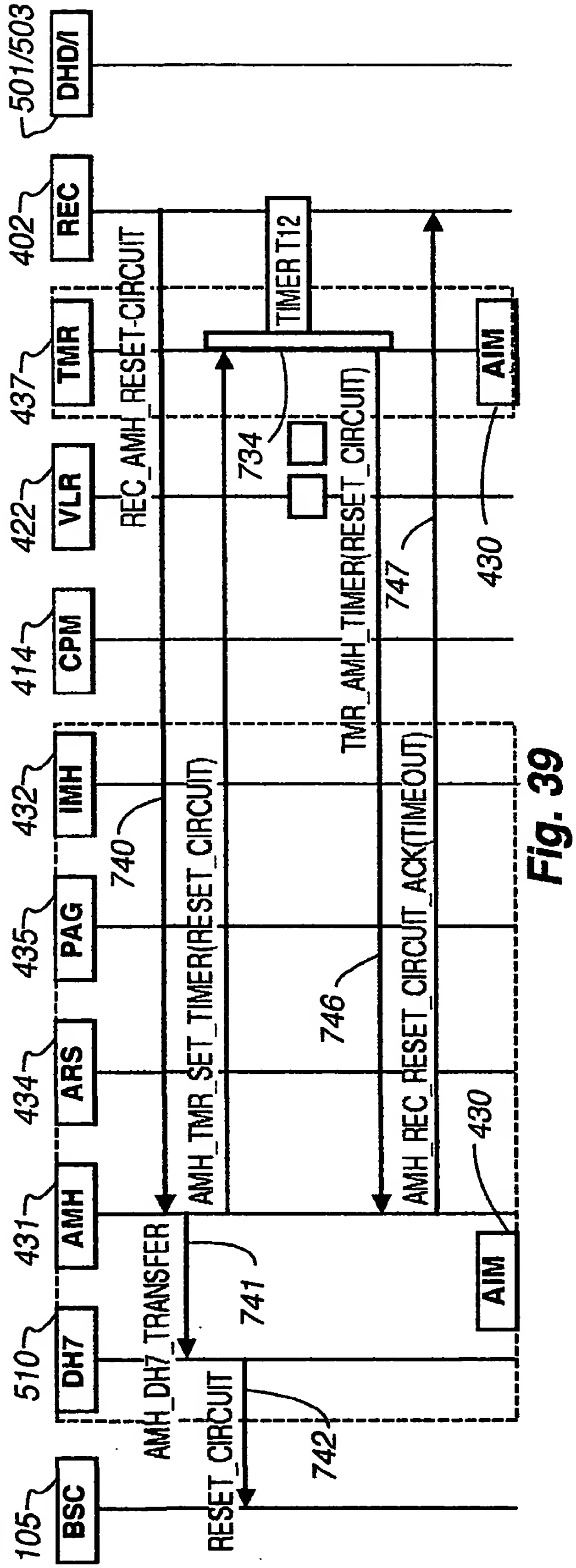
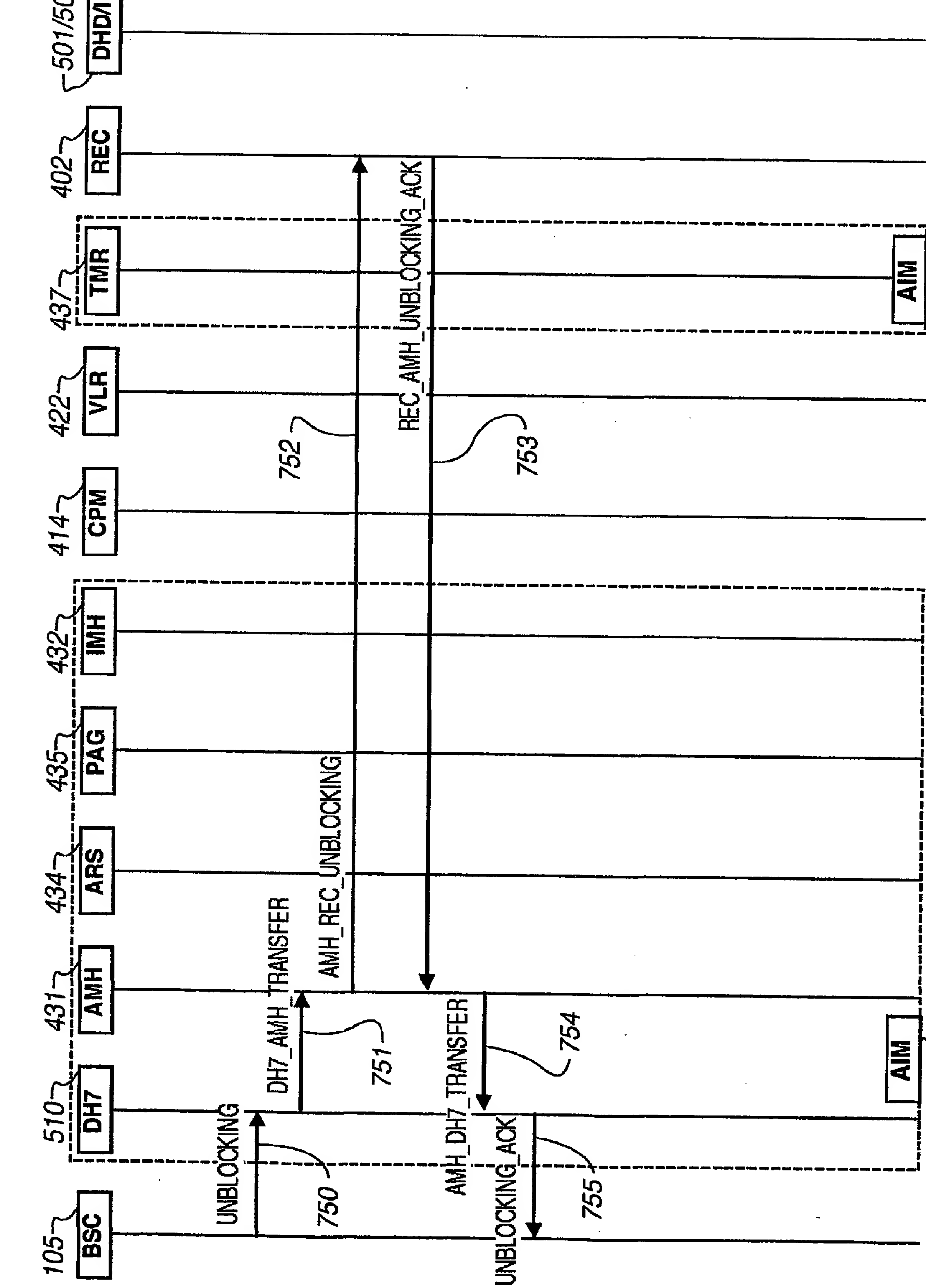
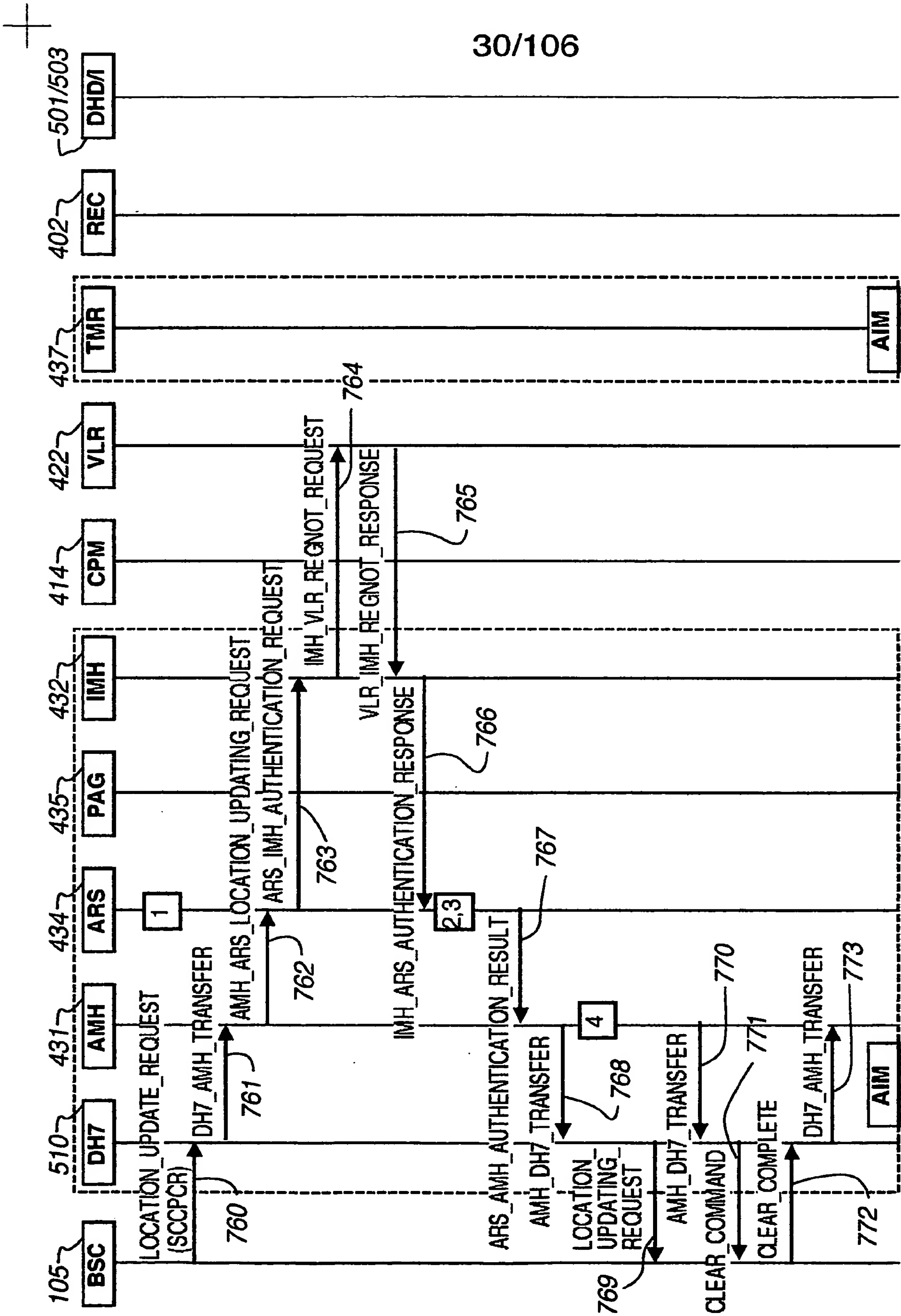

501/503
DHD/I
402
REC
437
TMR
422
VLR
414
CPM
432
IMH
435
PAG
434
ARS
431
AMH
510
DH7
105
BSC
REC_AMH_RESET-CIRCUIT
TIMER T12
AIM
734
TMR_AMH_TIMER(RESET_CIRCUIT)
747
430
740
AMH_TMR_SET_TIMER(RESET_CIRCUIT)
746
AMH_REC_RESET_CIRCUIT_ACK(TIMEOUT)
AMH_DH7_TRANSFER
741
RESET_CIRCUIT
742

Fig. 39



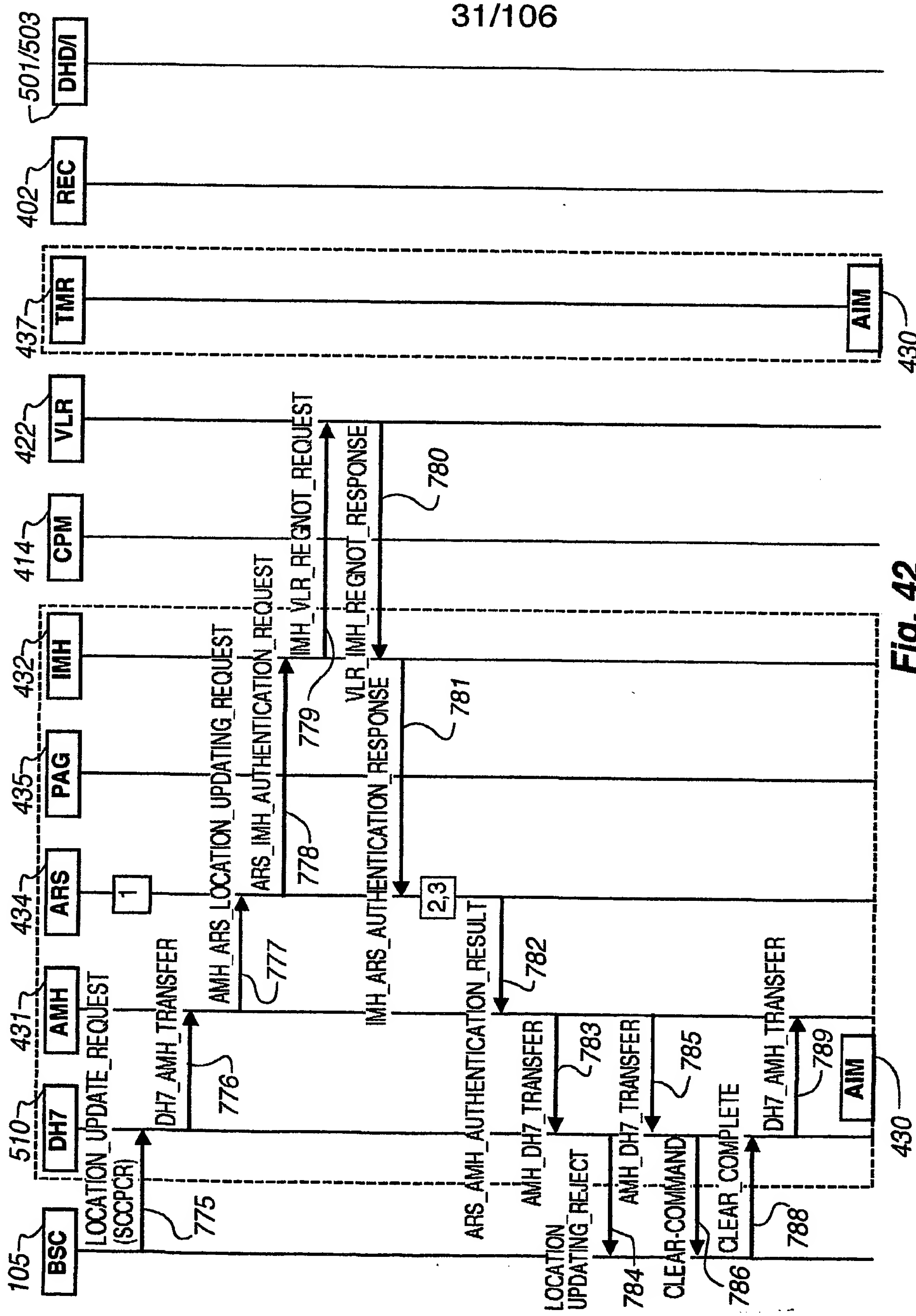
501/503
DHD/I
402
REC
437
TMR
422
VLR
414
CPM
432
IMH
435
PAG
434
ARS
431
AMH
510
DH7
105
BSC
AIM
430
AIM
430
UNBLOCKING
750
DH7_AMH_TRANSFER
751
AMH_REC_UNBLOCKING
752
REC_AMH_UNBLOCKING_ACK
753
AMH_DH7_TRANSFER
754
UNBLOCKING_ACK
755

Fig. 40



105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
402 REC
501/503 DHD/I
AIM 430
AIM 430
LOCATION_UPDATE_REQUEST (SCCPCR)
760
DH7_AMH_TRANSFER
761
AMH_ARS_LOCATION_UPDATING_REQUEST
762
1
ARS_IMH_AUTHENTICATION_REQUEST
763
IMH_VLR_REGNOT_REQUEST
764
VLR_IMH_REGNOT_RESPONSE
765
IMH_ARS_AUTHENTICATION_RESPONSE
766
2,3
ARS_AMH_AUTHENTICATION_RESULT
767
4
AMH_DH7_TRANSFER
768
LOCATION_UPDATING_REQUEST
769
AMH_DH7_TRANSFER
770
CLEAR_COMMAND
771
CLEAR_COMPLETE
772
DH7_AMH_TRANSFER
773

Fig. 41



BSC
105
DH7
510
AMH
431
ARS
434
PAG
435
IMH
432
CPM
414
VLR
422
TMR
437
REC
402
DHD/I
501/503
AIM
430
LOCATION_UPDATE_REQUEST (SCCPCR)
775
DH7_AMH_TRANSFER
776
AMH_ARS_LOCATION_UPDATING_REQUEST
777
1
ARS_IMH_AUTHENTICATION_REQUEST
778
IMH_VLR_REGNOT_REQUEST
779
VLR_IMH_REGNOT_RESPONSE
780
IMH_ARS_AUTHENTICATION_RESPONSE
781
2,3
ARS_AMH_AUTHENTICATION_RESULT
782
AMH_DH7_TRANSFER
783
LOCATION UPDATING_REJECT
784
AMH_DH7_TRANSFER
785
CLEAR-COMMAND
786
CLEAR_COMPLETE
788
DH7_AMH_TRANSFER
789

Fig. 42

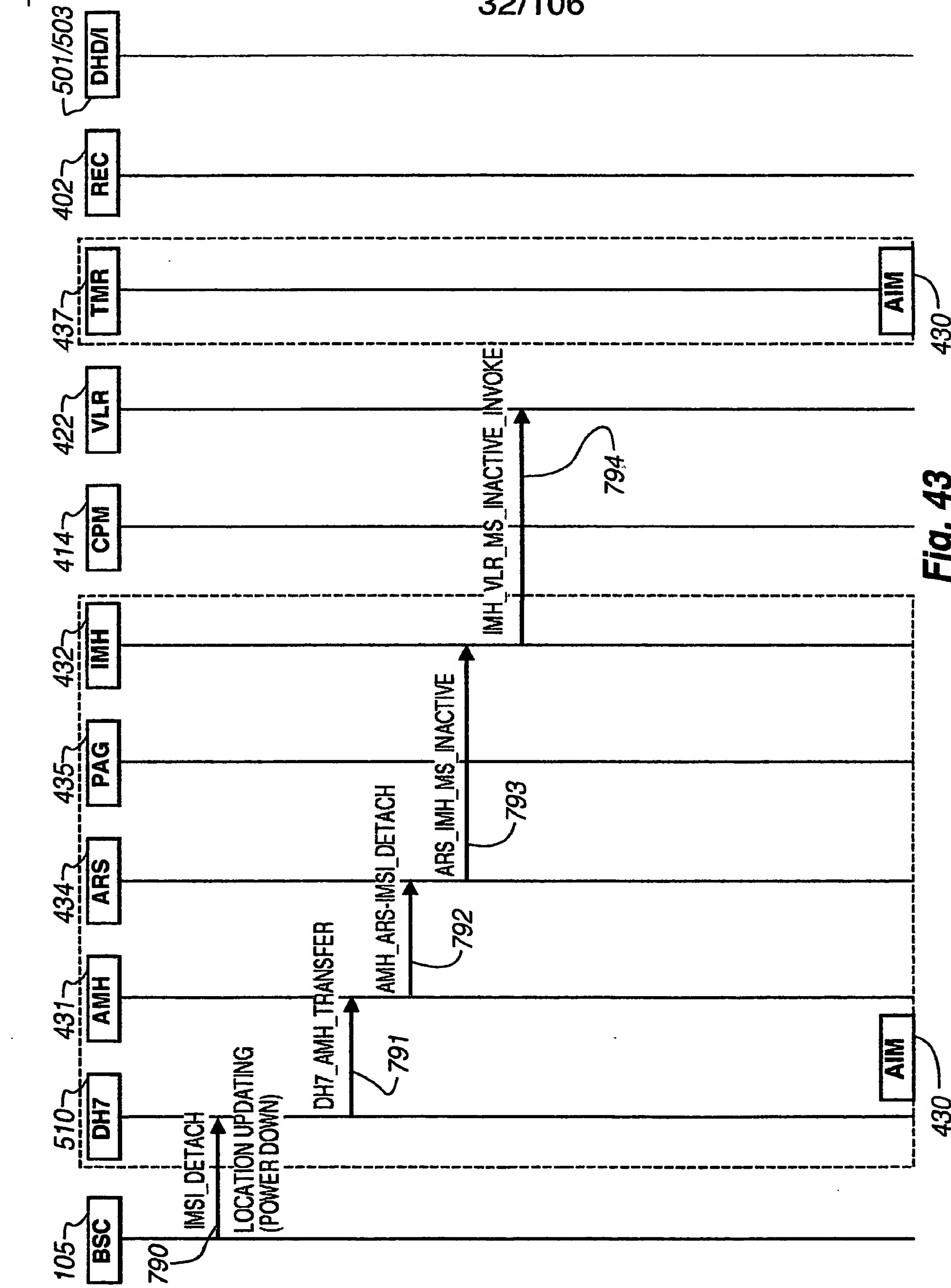
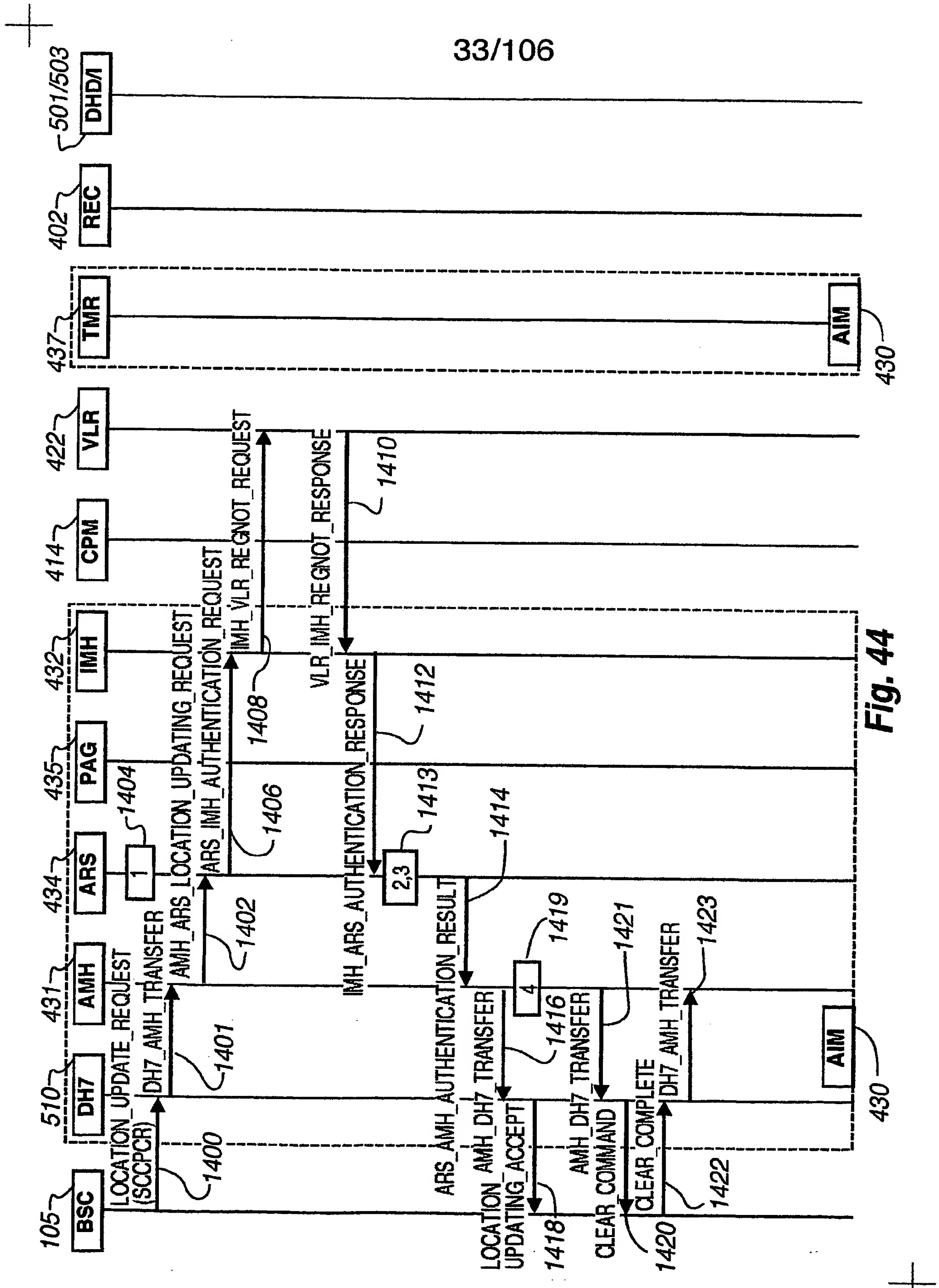
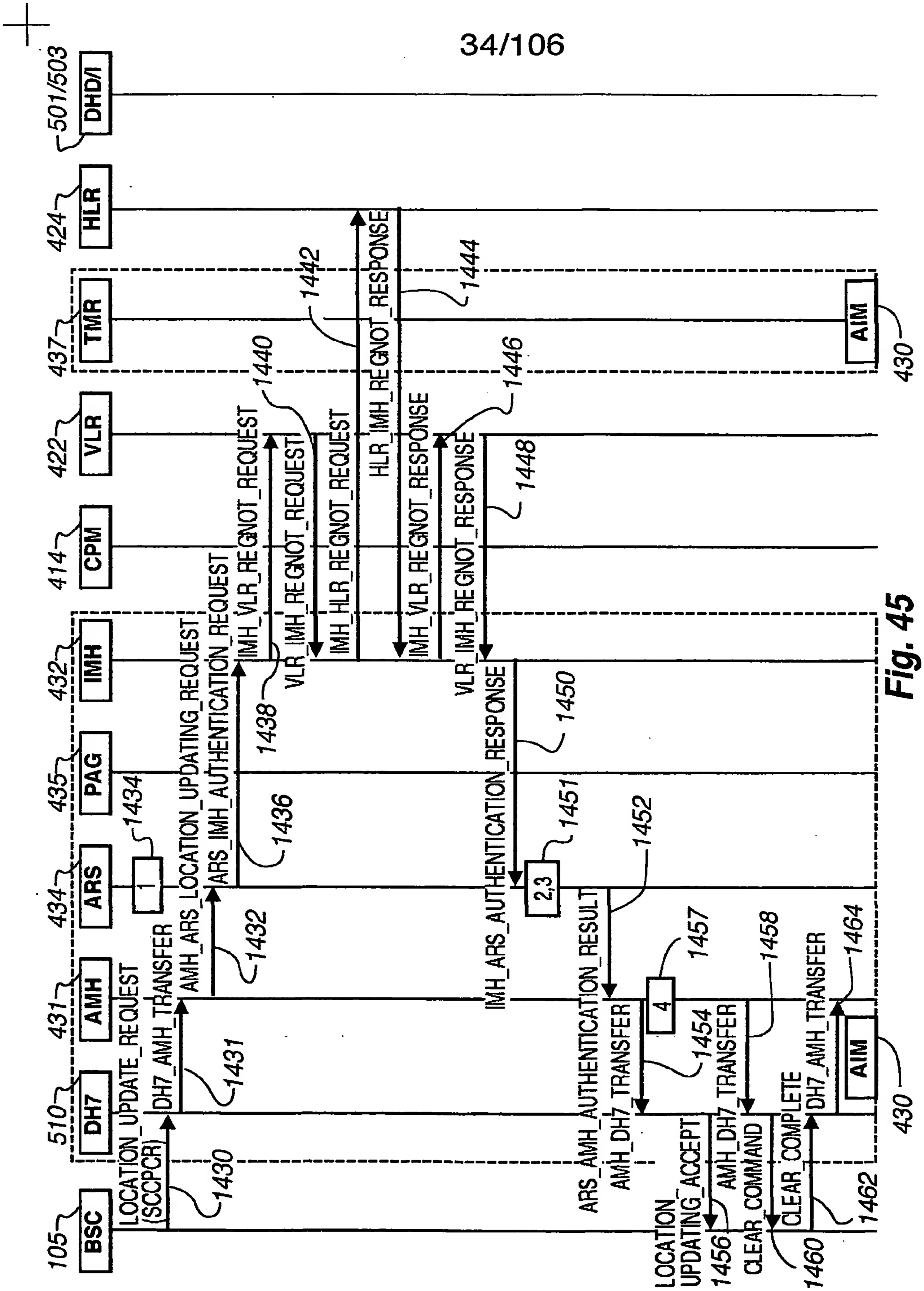

501/503
DHD/I
402
REC
437
TMR
AIM
430
422
VLR
414
CPM
432
IMH
435
PAG
434
ARS
431
AMH
510
DH7
AIM
430
105
BSC
790
IMSI_DETACH
LOCATION UPDATING
(POWER DOWN)
DH7_AMH_TRANSFER
791
AMH_ARS-IMSI_DETACH
792
ARS_IMH_MS_INACTIVE
793
IMH_VLR_MS_INACTIVE_INVOKE
794

Fig. 43



105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
402
REC
501/503
DHD/I
AIM
430
LOCATION_UPDATE_REQUEST (SCCPCR)
1400
DH7_AMH_TRANSFER
1401
AMH_ARS_LOCATION_UPDATING_REQUEST
1402
1
1404
ARS_IMH_AUTHENTICATION_REQUEST
1406
IMH_VLR_REGNOT_REQUEST
1408
VLR_IMH_REGNOT_RESPONSE
1410
IMH_ARS_AUTHENTICATION_RESPONSE
1412
2,3
1413
ARS_AMH_AUTHENTICATION_RESULT
1414
AMH_DH7_TRANSFER
1416
4
1419
LOCATION_UPDATING_ACCEPT
1418
AMH_DH7_TRANSFER
1421
CLEAR_COMMAND
1420
CLEAR_COMPLETE
1422
DH7_AMH_TRANSFER
1423

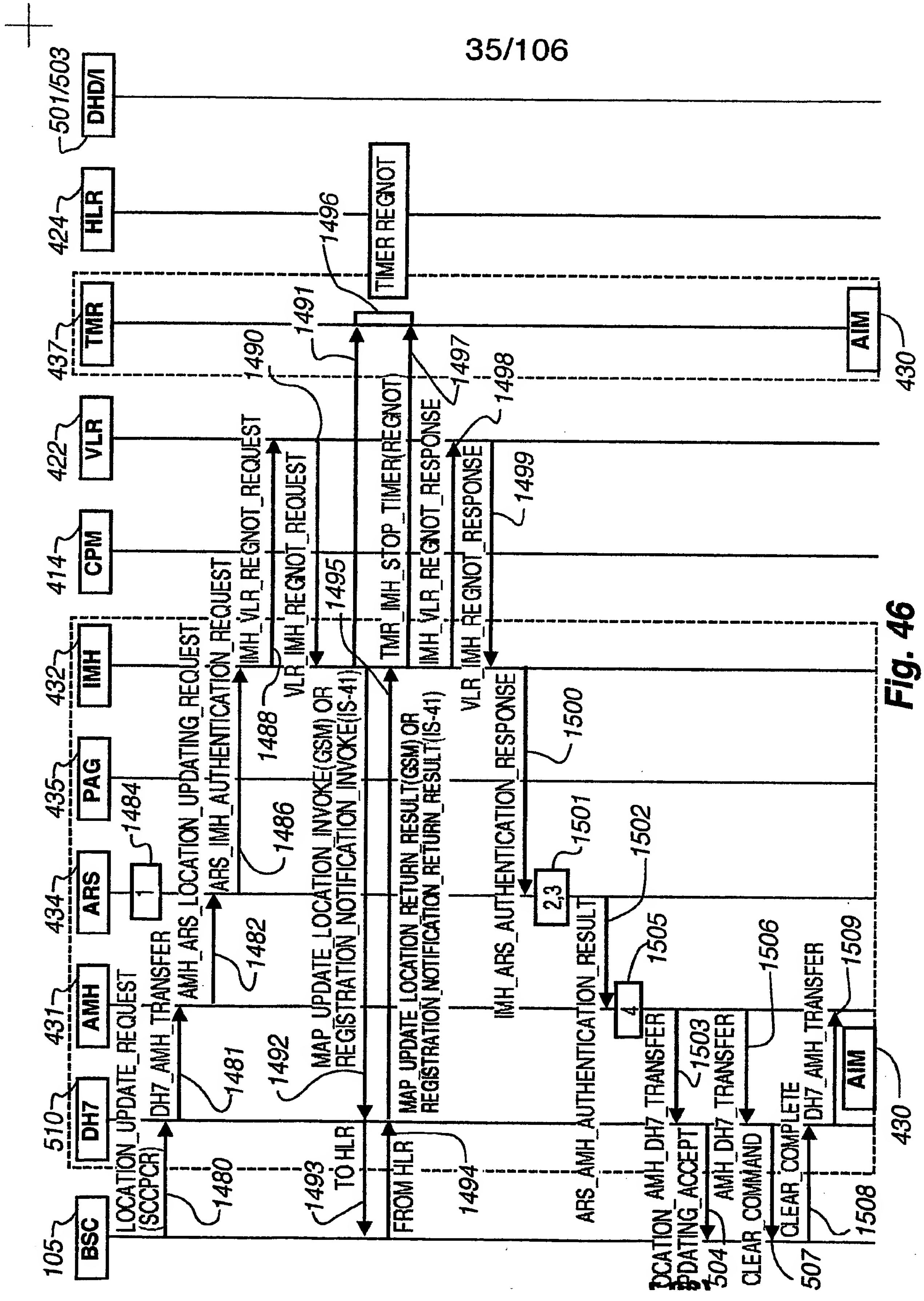
Fig. 44



105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
424
HLR
501/503
DHD/I
AIM
430
LOCATION_UPDATE_REQUEST (SCCPCR)
1430
DH7_AMH_TRANSFER
1431
AMH_ARS_TRANSFER
1432
1
1434
ARS_LOCATION_UPDATING_REQUEST
ARS_IMH_AUTHENTICATION_REQUEST
1436
IMH_VLR_REGNOT_REQUEST
1438
VLR_IMH_REGNOT_REQUEST
1440
IMH_HLR_REGNOT_REQUEST
1442
HLR_IMH_REGNOT_RESPONSE
1444
IMH_VLR_REGNOT_RESPONSE
1446
VLR_IMH_REGNOT_RESPONSE
1448
IMH_ARS_AUTHENTICATION_RESPONSE
1450
2,3
1451
ARS_AMH_AUTHENTICATION_RESULT
1452
4
1457
AMH_DH7_TRANSFER
1454
LOCATION_UPDATING_ACCEPT
1456
AMH_DH7_TRANSFER
1458
CLEAR_COMMAND
1460
CLEAR_COMPLETE
1462
DH7_AMH_TRANSFER
1464

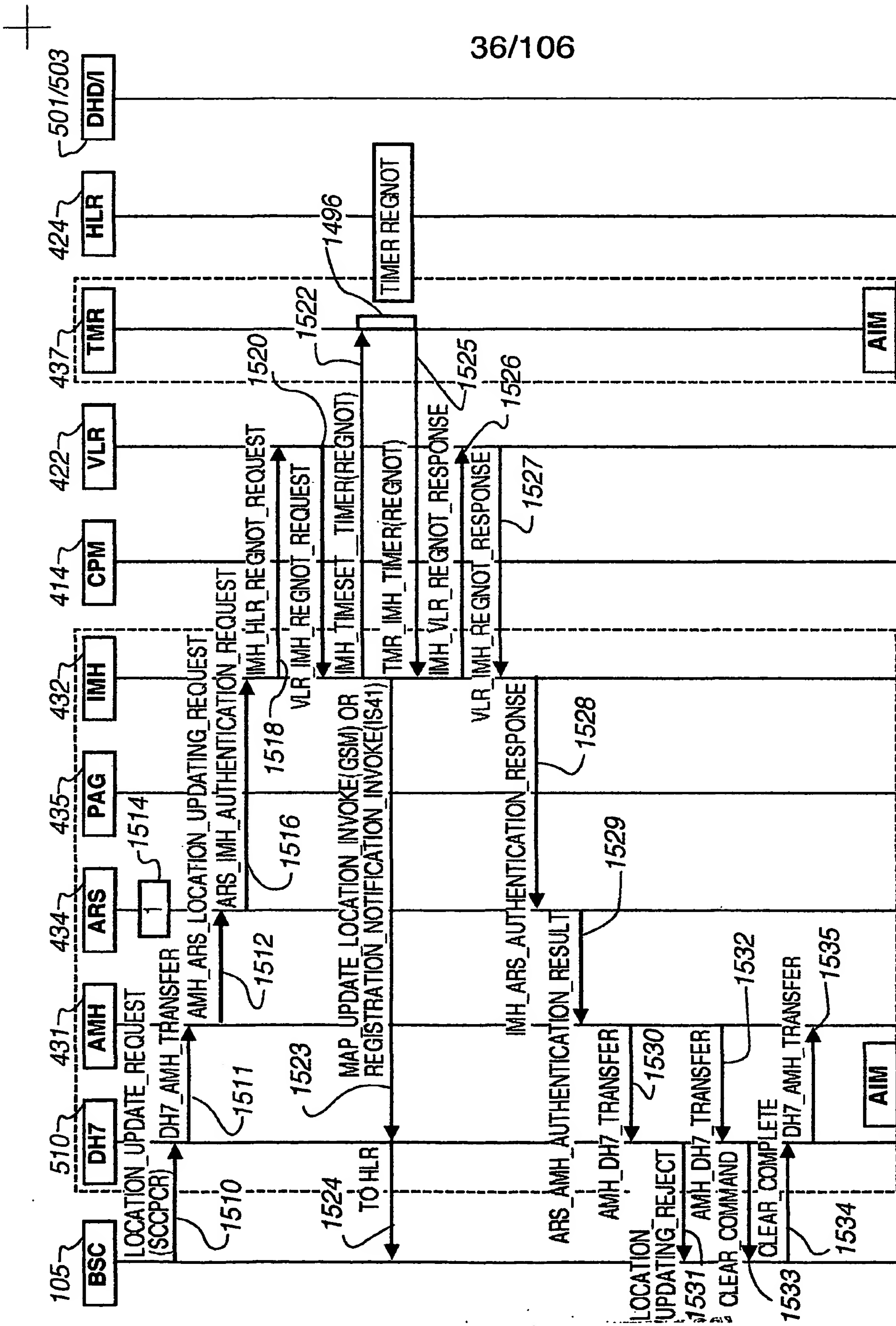
Fig. 45

35/106



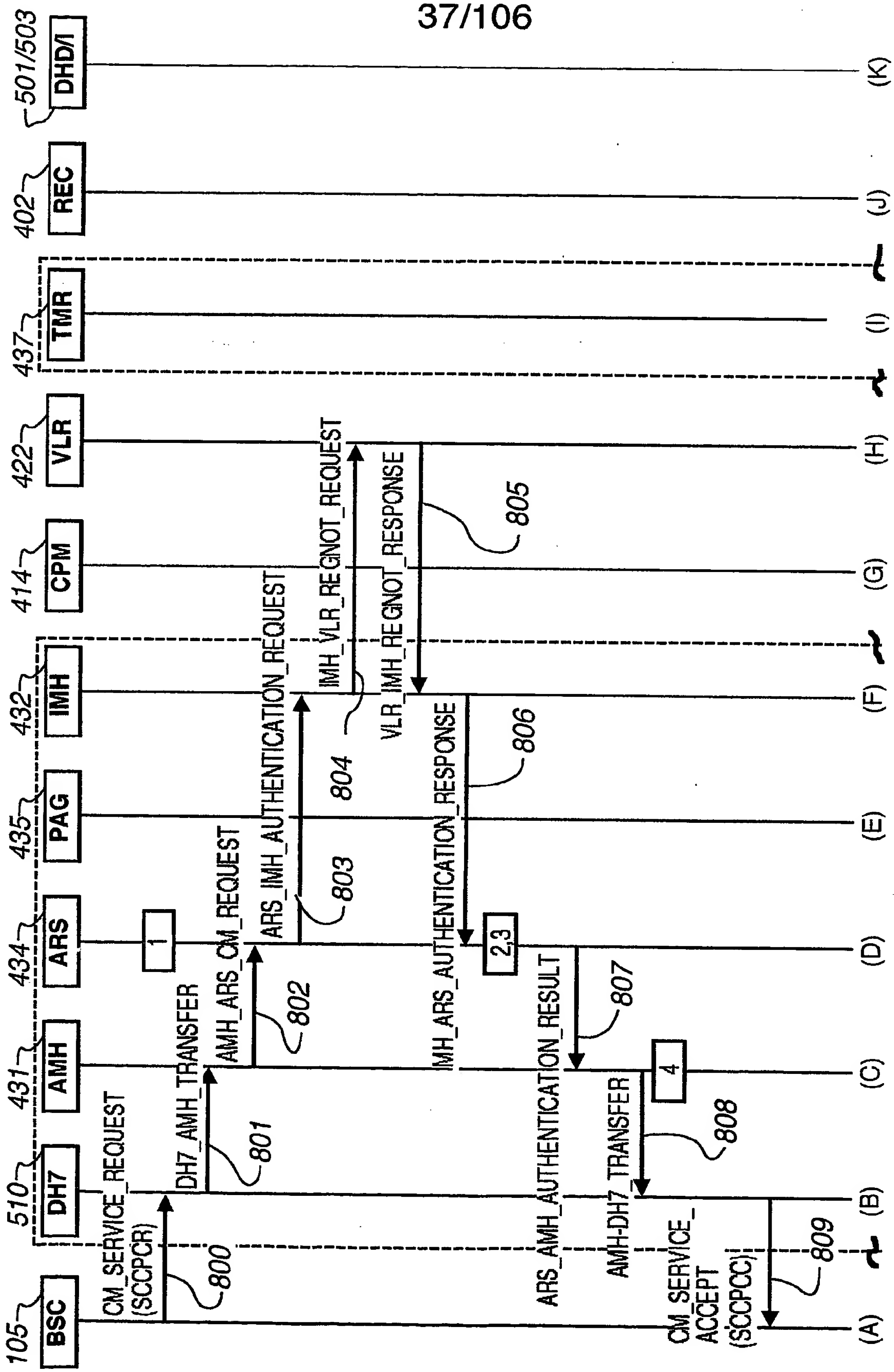
105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
424 HLR
501/503 DHD/I
430 AIM
1484 1
LOCATION_UPDATE_REQUEST (SCCPCR)
1480
DH7_AMH_TRANSFER
1481
AMH_ARS_LOCATION_UPDATING_REQUEST
1482
ARS_IMH_AUTHENTICATION_REQUEST
1486
IMH_VLR_REGNOT_REQUEST
1488
VLR_IMH_REGNOT_REQUEST
1490
MAP_UPDATE_LOCATION_INVOKE(GSM) OR REGISTRATION_NOTIFICATION_INVOKE(IS-41)
1492
TO HLR
1493
1491
1496 TIMER REGNOT
1495
FROM HLR
1494
MAP_UPDATE_LOCATION_RETURN_RESULT(GSM) OR REGISTRATION_NOTIFICATION_RETURN_RESULT(IS-41)
TMR_IMH_STOP_TIMER(REGNOT)
1497
IMH_VLR_REGNOT_RESPONSE
1498
VLR_IMH_REGNOT_RESPONSE
1499
IMH_ARS_AUTHENTICATION_RESPONSE
1500
2,3
1501
ARS_AMH_AUTHENTICATION_RESULT
1502
4
1505
AMH_DH7_TRANSFER
1503
LOCATION_UPDATING_ACCEPT
1504
AMH_DH7_TRANSFER
1506
CLEAR_COMMAND
1507
DH7_AMH_TRANSFER
1509
CLEAR_COMPLETE
1508

Fig. 46



105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
424
HLR
501/503
DHD/I
430
AIM
LOCATION_UPDATE_REQUEST (SCCPCR)
1510
DH7_AMH_TRANSFER
1511
AMH_ARS_TRANSFER
1512
1514
ARS_LOCATION_UPDATING_REQUEST
ARS_IMH_AUTHENTICATION_REQUEST
1516
IMH_HLR_REGNOT_REQUEST
1518
VLR_IMH_REGNOT_REQUEST
1520
IMH_TIMESET_TIMER(REGNOT)
1522
TIMER REGNOT
1496
TMR_IMH_TIMER(REGNOT)
1525
IMH_VLR_REGNOT_RESPONSE
1526
VLR_IMH_REGNOT_RESPONSE
1527
MAP_UPDATE_LOCATION_INVOKE(GSM) OR REGISTRATION_NOTIFICATION_INVOKE(IS41)
1523
TO HLR
1524
IMH_ARS_AUTHENTICATION_RESPONSE
1528
ARS_AMH_AUTHENTICATION_RESULT
1529
AMH_DH7_TRANSFER
1530
LOCATION_UPDATING_REJECT
1531
AMH_DH7_TRANSFER
1532
CLEAR_COMMAND
1533
CLEAR_COMPLETE
1534
DH7_AMH_TRANSFER
1535

Fig. 47



105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
402 REC
501/503 DHD/I
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
CM_SERVICE_REQUEST (SCCPCR)
800
DH7_AMH_TRANSFER
801
AMH_ARS_CM_REQUEST
802
ARS_IMH_AUTHENTICATION_REQUEST
803
IMH_VLR_REGNOT_REQUEST
804
VLR_IMH_REGNOT_RESPONSE
805
IMH_ARS_AUTHENTICATION_RESPONSE
806
ARS_AMH_AUTHENTICATION_RESULT
807
AMH-DH7_TRANSFER
808
CM_SERVICE_ACCEPT (SCCPCC)
809
1
2,3
4

Fig. 48A

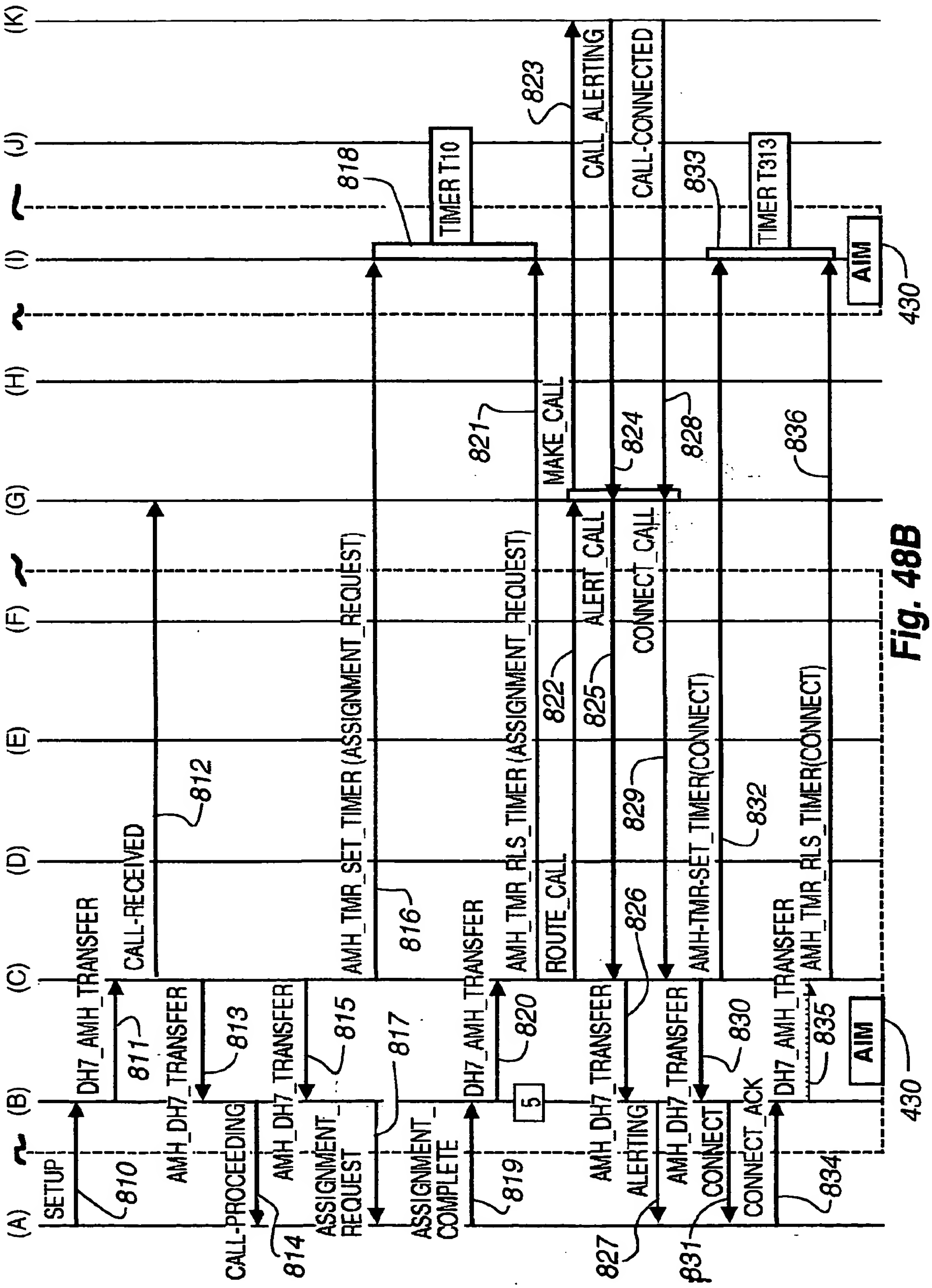
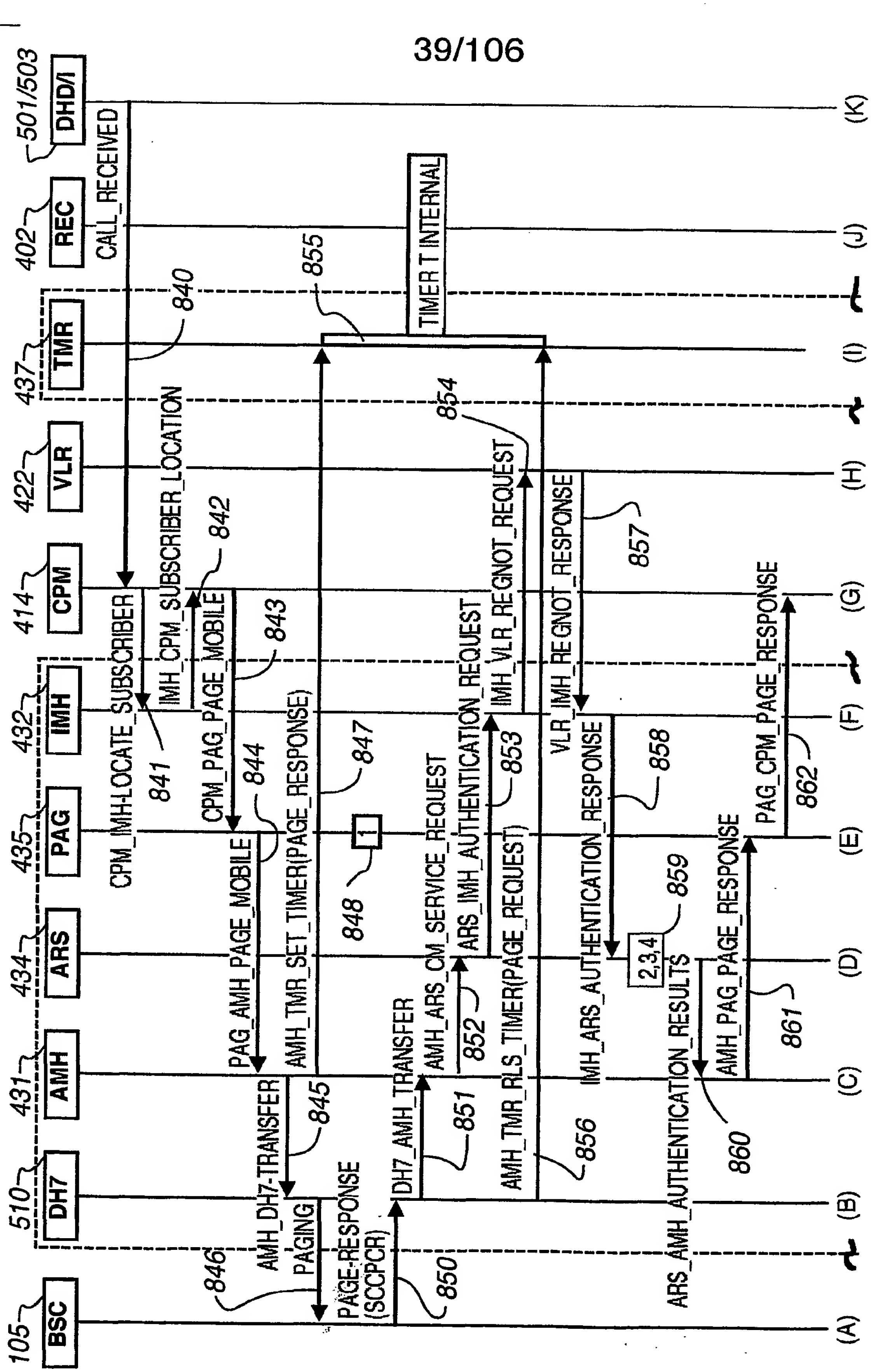

(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
SETUP
810
DH7_AMH_TRANSFER
811
CALL-RECEIVED
812
AMH_DH7_TRANSFER
813
CALL-PROCEEDING
814
AMH_DH7_TRANSFER
815
ASSIGNMENT_REQUEST
AMH_TMR_SET_TIMER (ASSIGNMENT_REQUEST)
816
817
ASSIGNMENT_COMPLETE
818
TIMER T10
819
DH7_AMH_TRANSFER
820
5
AMH_TMR_RLS_TIMER (ASSIGNMENT_REQUEST)
821
MAKE_CALL
ROUTE_CALL
822
823
CALL_ALERTING
ALERT_CALL
AMH_DH7_TRANSFER
824
825
826
ALERTING
827
CALL-CONNECTED
CONNECT_CALL
828
829
AMH_DH7_TRANSFER
CONNECT
830
831
AMH-TMR-SET_TIMER(CONNECT)
832
833
TIMER T313
CONNECT_ACK
834
DH7_AMH_TRANSFER
835
AMH_TMR_RLS_TIMER(CONNECT)
836
AIM
430

Fig. 48B



105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
402
REC
501/503
DHD/I
CALL_RECEIVED
840
CPM_IMH-LOCATE_SUBSCRIBER
841
IMH_CPM_SUBSCRIBER_LOCATION
842
CPM_PAG_PAGE_MOBILE
843
PAG_AMH_PAGE_MOBILE
844
AMH_DH7-TRANSFER
845
AMH_DH7_TRANSFER
PAGING
846
AMH_TMR_SET_TIMER(PAGE_RESPONSE)
847
1
848
PAGE-RESPONSE
(SCCPCR)
850
DH7_AMH_TRANSFER
851
AMH_ARS_CM_SERVICE_REQUEST
852
ARS_IMH_AUTHENTICATION_REQUEST
853
IMH_VLR_REGNOT_REQUEST
854
855
TIMER T INTERNAL
AMH_TMR_RLS_TIMER(PAGE_REQUEST)
856
VLR_IMH_REGNOT_RESPONSE
857
IMH_ARS_AUTHENTICATION_RESPONSE
858
2,3,4
859
ARS_AMH_AUTHENTICATION_RESULTS
860
AMH_PAG_PAGE_RESPONSE
861
PAG_CPM_PAGE_RESPONSE
862
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)

Fig. 49A

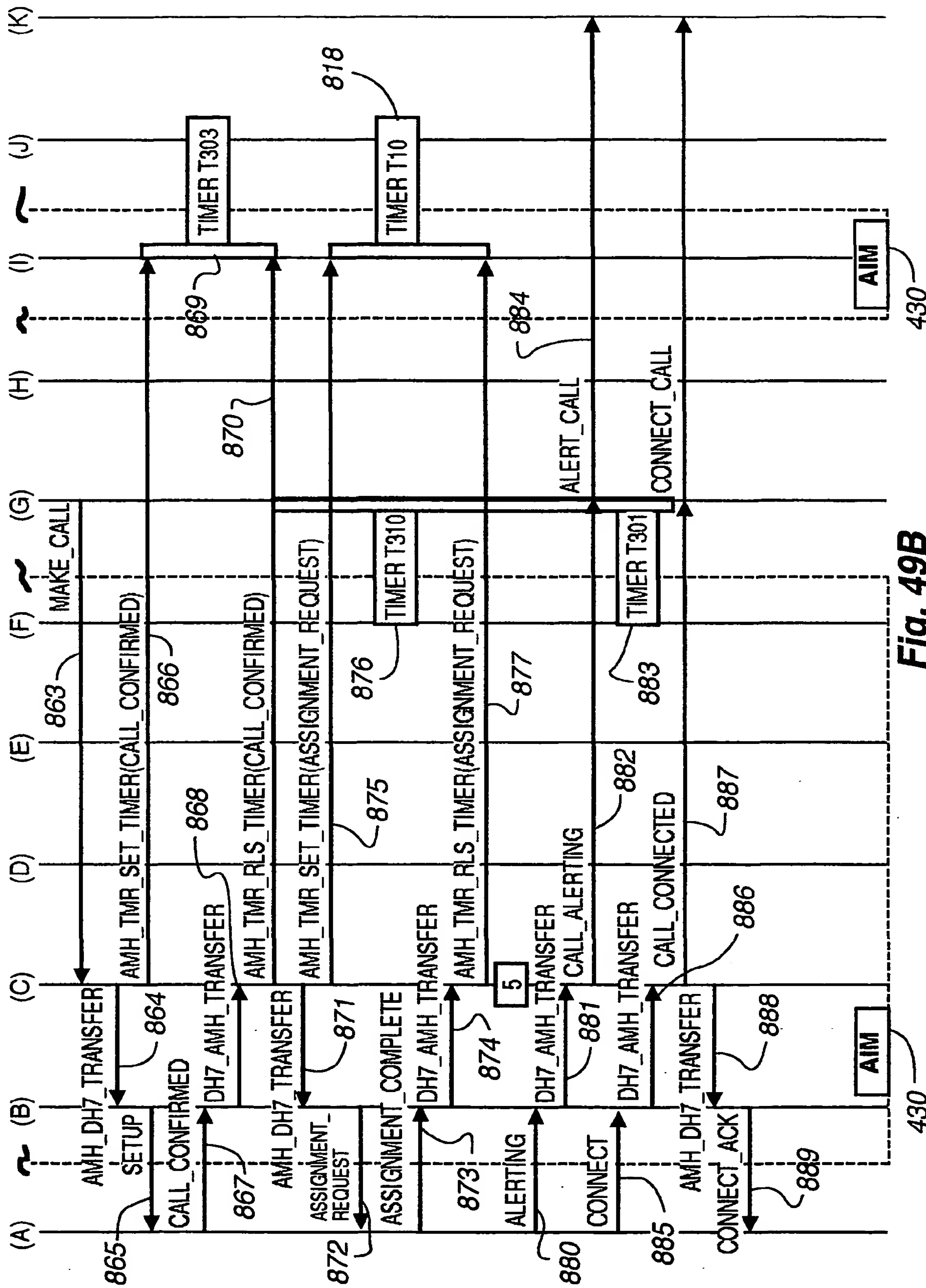

(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
MAKE_CALL
863
AMH_DH7_TRANSFER
SETUP
865
CALL_CONFIRMED
864
AMH_TMR_SET_TIMER(CALL_CONFIRMED)
866
869
TIMER T303
867
DH7_AMH_TRANSFER
868
AMH_TMR_RLS_TIMER(CALL_CONFIRMED)
870
AMH_DH7_TRANSFER
AMH_DH7_ASSIGNMENT_REQUEST
872
871
AMH_TMR_SET_TIMER(ASSIGNMENT_REQUEST)
875
876
TIMER T310
TIMER T10
818
ASSIGNMENT_COMPLETE
873
DH7_AMH_TRANSFER
874
AMH_TMR_RLS_TIMER(ASSIGNMENT_REQUEST)
877
5
ALERTING
880
DH7_AMH_TRANSFER
881
CALL_ALERTING
882
883
TIMER T301
ALERT_CALL
884
CONNECT
885
DH7_AMH_TRANSFER
CALL_CONNECTED
886
887
CONNECT_CALL
AMH_DH7_TRANSFER
CONNECT_ACK
889
888
AIM
430
AIM
430

Fig. 49B

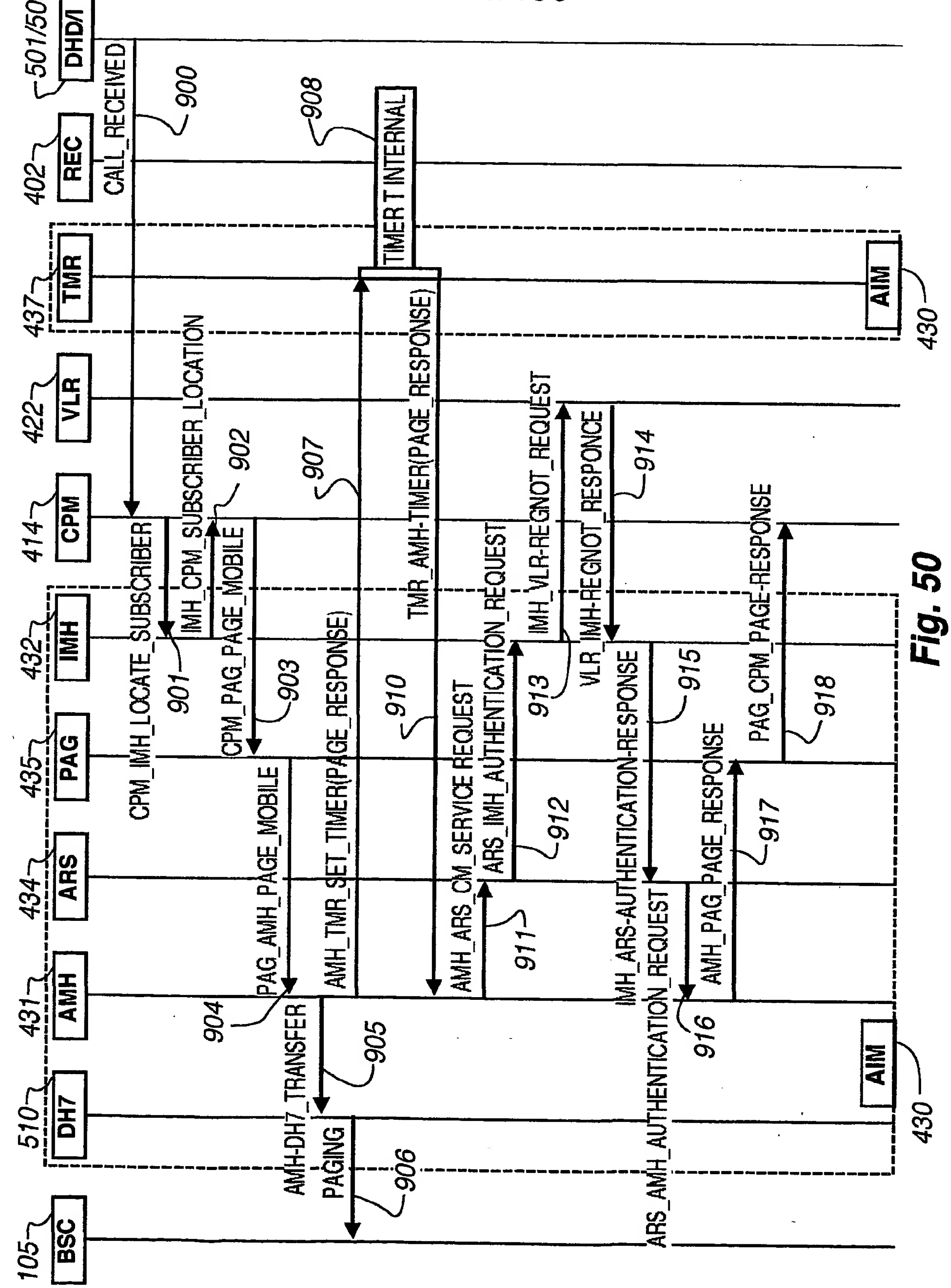
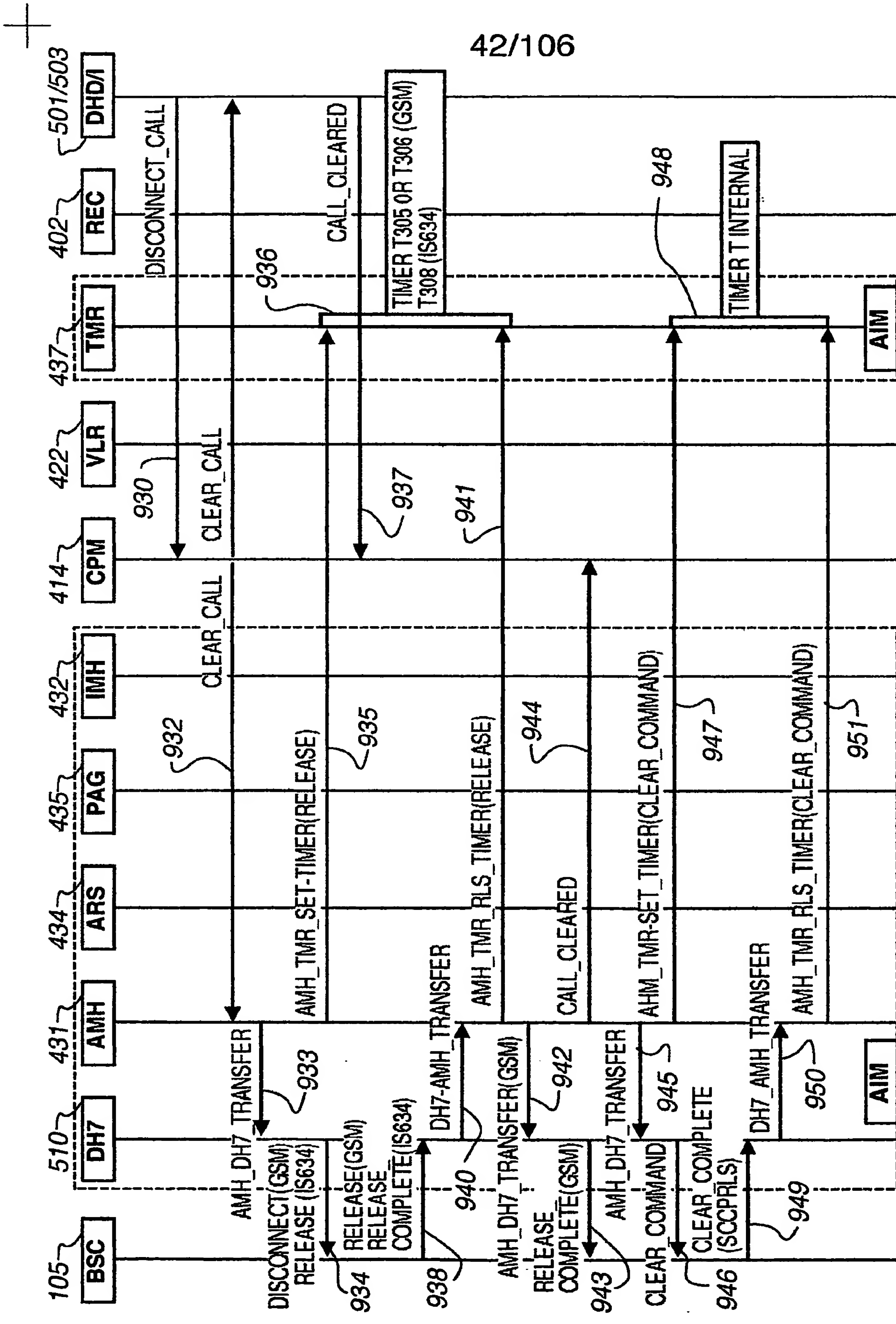

501/503
DHD/I
402
REC
437
TMR
422
VLR
414
CPM
432
IMH
435
PAG
434
ARS
431
AMH
510
DH7
105
BSC
430
AIM
CALL_RECEIVED
900
CPM_IMH_LOCATE_SUBSCRIBER
901
IMH_CPM_SUBSCRIBER_LOCATION
902
CPM_PAG_PAGE_MOBILE
903
PAG_AMH_PAGE_MOBILE
904
AMH-DH7_TRANSFER
905
PAGING
906
AMH_TMR_SET_TIMER(PAGE_RESPONSE)
907
TIMER T INTERNAL
908
TMR_AMH-TIMER(PAGE_RESPONSE)
910
AMH_ARS_CM_SERVICE REQUEST
911
ARS_IMH_AUTHENTICATION_REQUEST
912
IMH_VLR-REGNOT_REQUEST
913
VLR_IMH-REGNOT_RESPONCE
914
IMH_ARS-AUTHENTICATION-RESPONSE
915
ARS_AMH_AUTHENTICATION_REQUEST
916
AMH_PAG_PAGE_RESPONSE
917
PAG_CPM_PAGE-RESPONSE
918

Fig. 50



105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
402 REC
501/503 DHD/I
430 AIM
DISCONNECT_CALL
930
CLEAR_CALL
CLEAR_CALL
932
AMH_DH7_TRANSFER
933
DISCONNECT(GSM)
RELEASE (IS634)
934
AMH_TMR_SET-TIMER(RELEASE)
935
936
TIMER T305 OR T306 (GSM)
T308 (IS634)
CALL_CLEARED
937
RELEASE(GSM)
RELEASE
COMPLETE(IS634)
938
DH7-AMH_TRANSFER
940
AMH_TMR_RLS_TIMER(RELEASE)
941
AMH_DH7_TRANSFER(GSM)
942
AMH_DH7_TRANSFER
RELEASE
COMPLETE(GSM)
943
CALL_CLEARED
944
AMH_DH7_TRANSFER
945
CLEAR_COMMAND
946
AHM_TMR-SET_TIMER(CLEAR_COMMAND)
947
948
TIMER T INTERNAL
CLEAR_COMPLETE
(SCCPRLS)
949
DH7_AMH_TRANSFER
950
AMH_TMR_RLS_TIMER(CLEAR_COMMAND)
951

Fig. 51

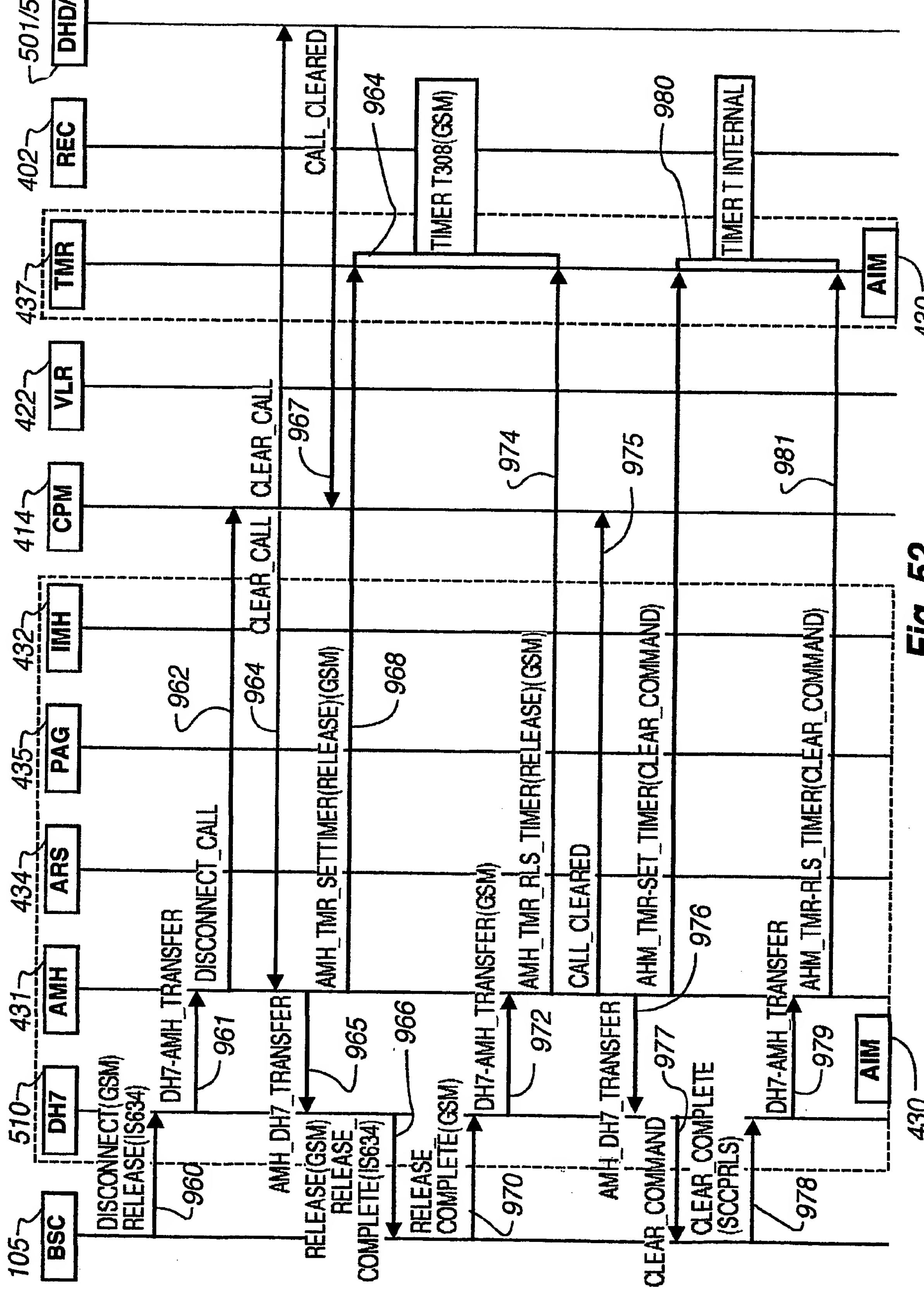

105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
402 REC
501/503 DHD/I
430 AIM
DISCONNECT(GSM) RELEASE(IS634)
960
DH7-AMH_TRANSFER
961
AMH_TRANSFER DISCONNECT_CALL
962
CLEAR_CALL
964
CLEAR_CALL
967
CALL_CLEARED
AMH_DH7_TRANSFER
965
RELEASE(GSM) RELEASE COMPLETE(IS634)
966
AMH_TMR_SETTIMER(RELEASE)(GSM)
968
964
TIMER T308(GSM)
RELEASE COMPLETE(GSM)
970
DH7-AMH_TRANSFER
972
AMH_TRANSFER(GSM)
AMH_TMR_RLS_TIMER(RELEASE)(GSM)
974
CALL_CLEARED
975
AMH_DH7_TRANSFER
976
AHM_TMR-SET_TIMER(CLEAR_COMMAND)
977
CLEAR_COMMAND
980
TIMER T INTERNAL
CLEAR_COMPLETE (SCCPRLS)
978
DH7-AMH_TRANSFER
979
AMH_TRANSFER
AHM_TMR-RLS_TIMER(CLEAR_COMMAND)
981

Fig. 52

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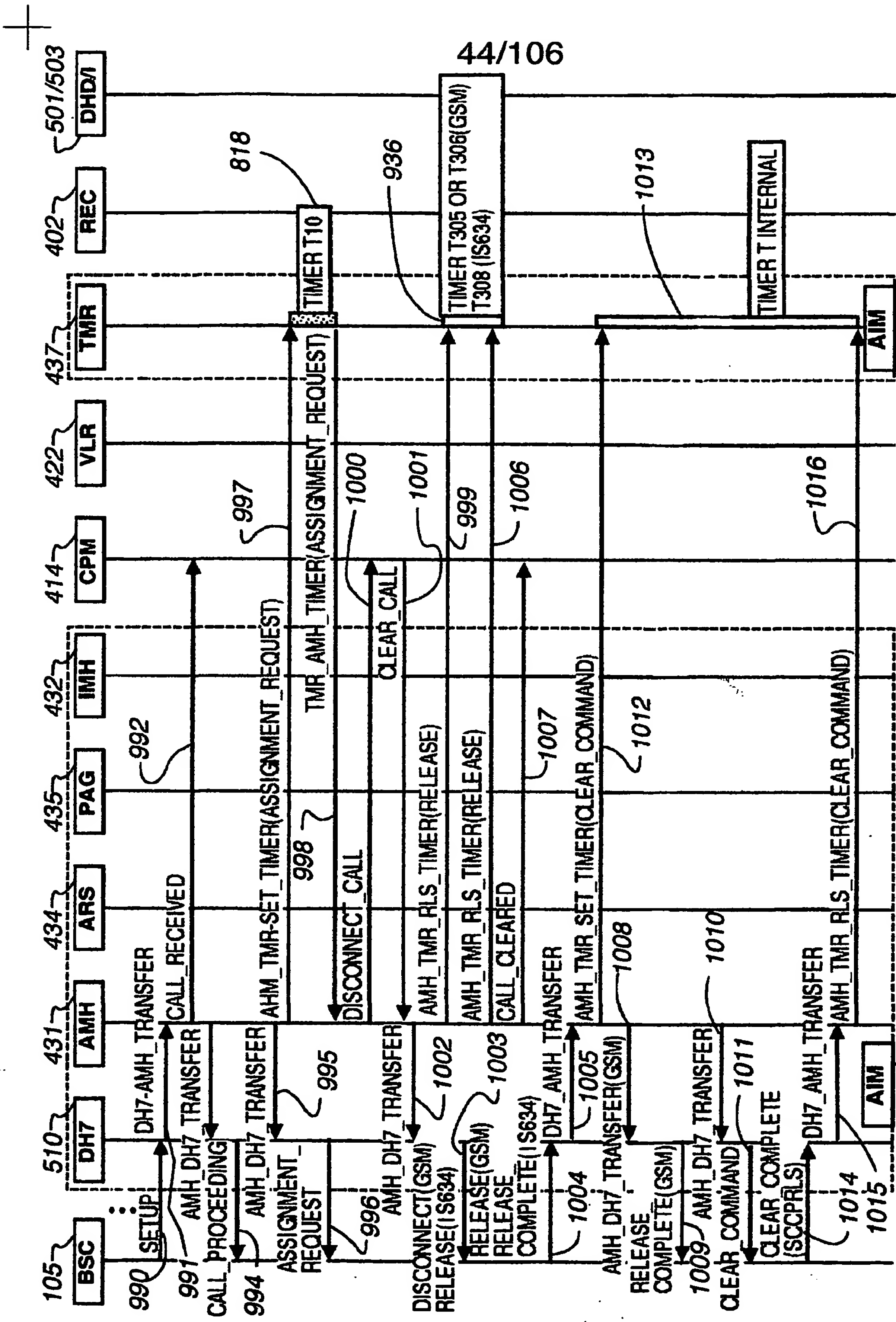


Fig. 53

SUBSTITUTE SHEET (RULE 26)

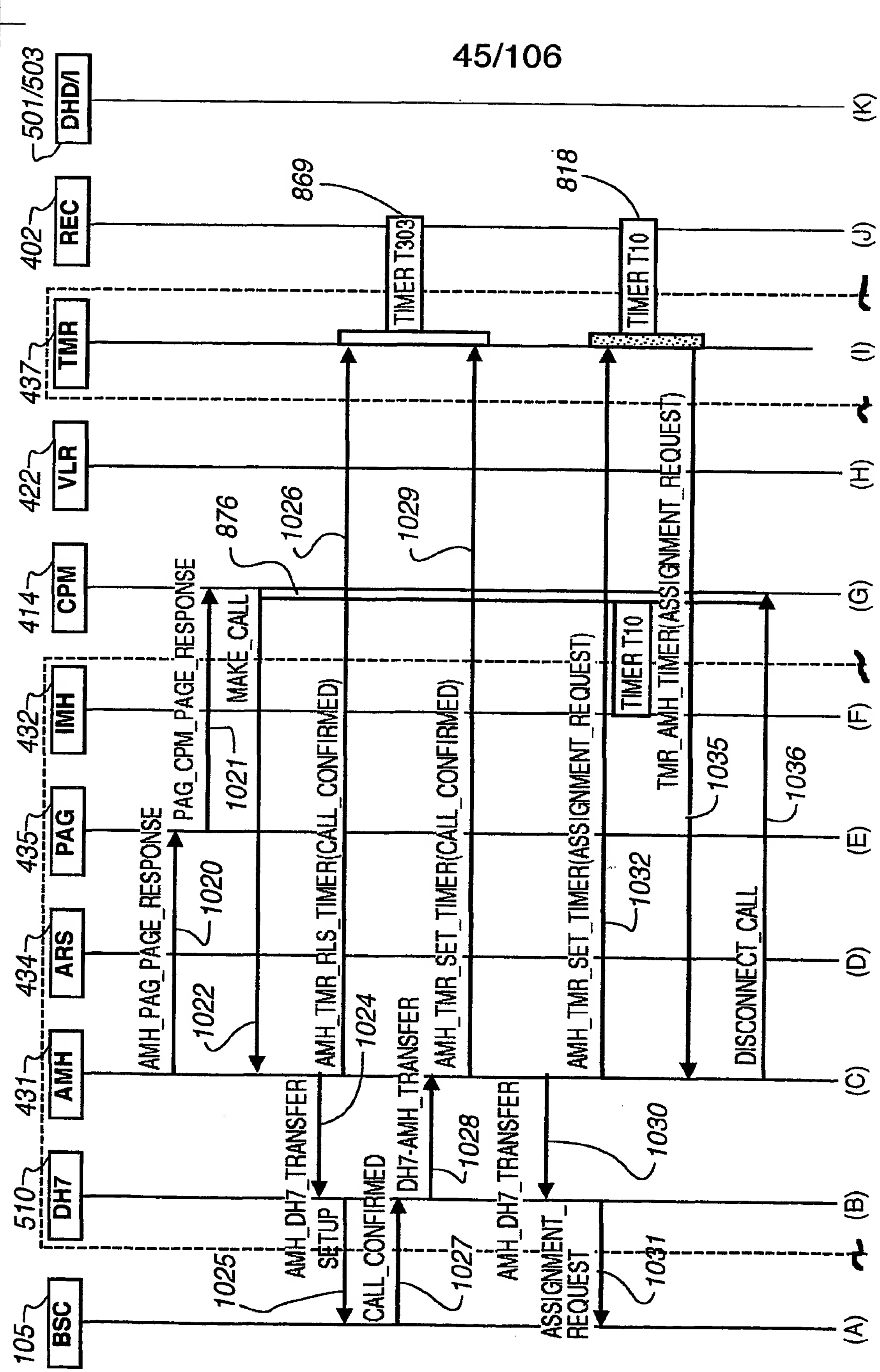

105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
402 REC
501/503 DHD/I
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
AMH_PAG_PAGE_RESPONSE
1020
PAG_CPM_PAGE_RESPONSE
1021
MAKE_CALL
876
1022
AMH_TMR_RLS_TIMER(CALL_CONFIRMED)
1024
1026
AMH_DH7_TRANSFER
AMH_DH7_TRANSFER SETUP
1025
CALL_CONFIRMED
1027
DH7-AMH_TRANSFER
1028
AMH_TMR_SET_TIMER(CALL_CONFIRMED)
1029
869
TIMER T303
AMH_DH7_TRANSFER
1030
AMH_DH7_TRANSFER
ASSIGNMENT_REQUEST
1031
AMH_TMR_SET_TIMER(ASSIGNMENT_REQUEST)
1032
TIMER T10
818
TIMER T10
TMR_AMH_TIMER(ASSIGNMENT_REQUEST)
1035
DISCONNECT_CALL
1036

Fig. 54A

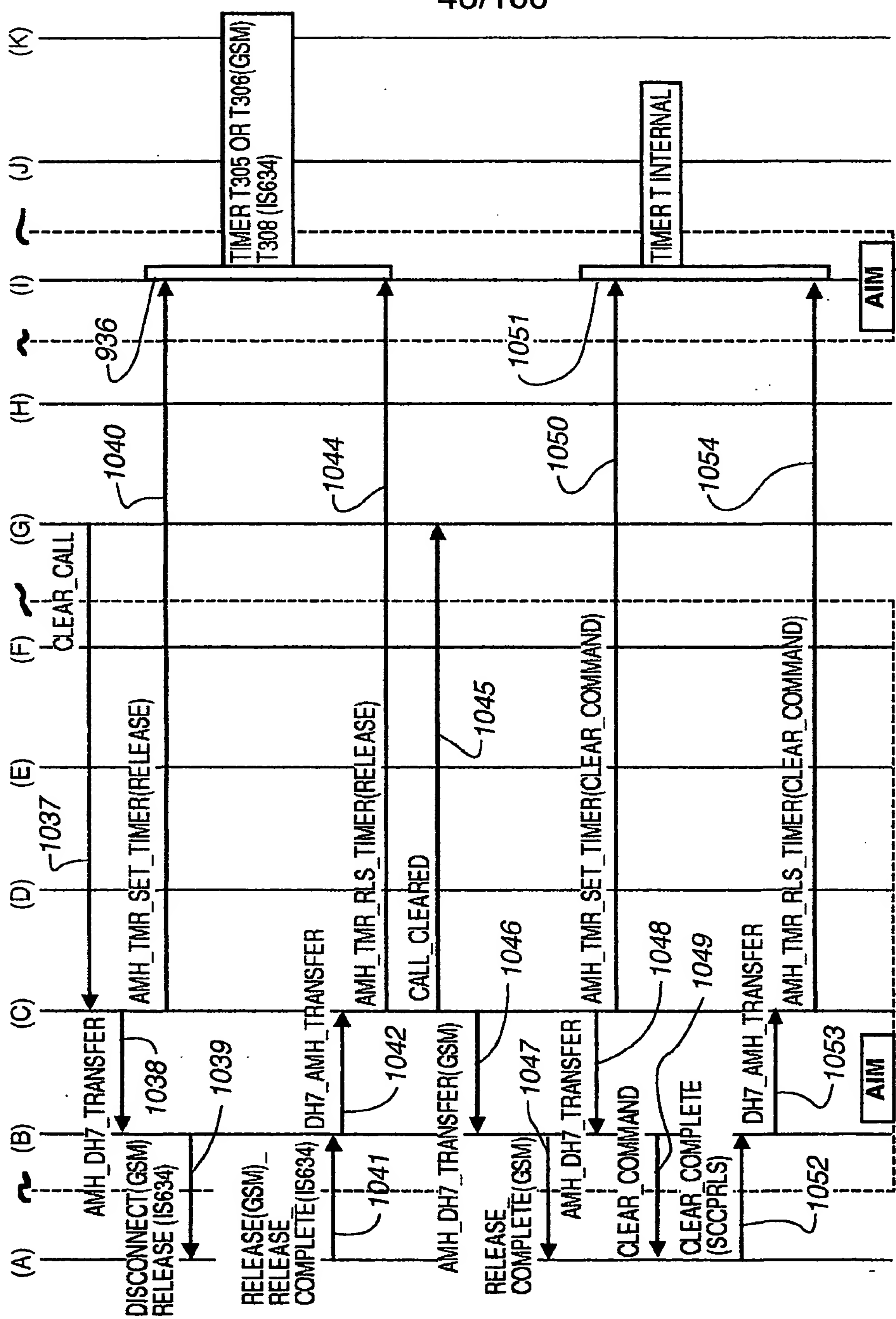

(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
CLEAR_CALL
1037
AMH_DH7_TRANSFER
1038
DISCONNECT(GSM)
RELEASE (IS634)
1039
AMH_TMR_SET_TIMER(RELEASE)
1040
936
TIMER T305 OR T306(GSM)
T308 (IS634)
RELEASE(GSM)_
RELEASE_
COMPLETE(IS634)
1041
DH7_AMH_TRANSFER
1042
AMH_TMR_RLS_TIMER(RELEASE)
1044
CALL_CLEARED
1045
AMH_DH7_TRANSFER(GSM)
1046
RELEASE_
COMPLETE(GSM)
1047
AMH_DH7_TRANSFER
1048
CLEAR_COMMAND
AMH_TMR_SET_TIMER(CLEAR_COMMAND)
1050
1051
TIMER T INTERNAL
CLEAR_COMPLETE
(SCCPRLS)
1049
1052
DH7_AMH_TRANSFER
1053
AMH_TMR_RLS_TIMER(CLEAR_COMMAND)
1054
AIM
430
AIM
430

Fig. 54B

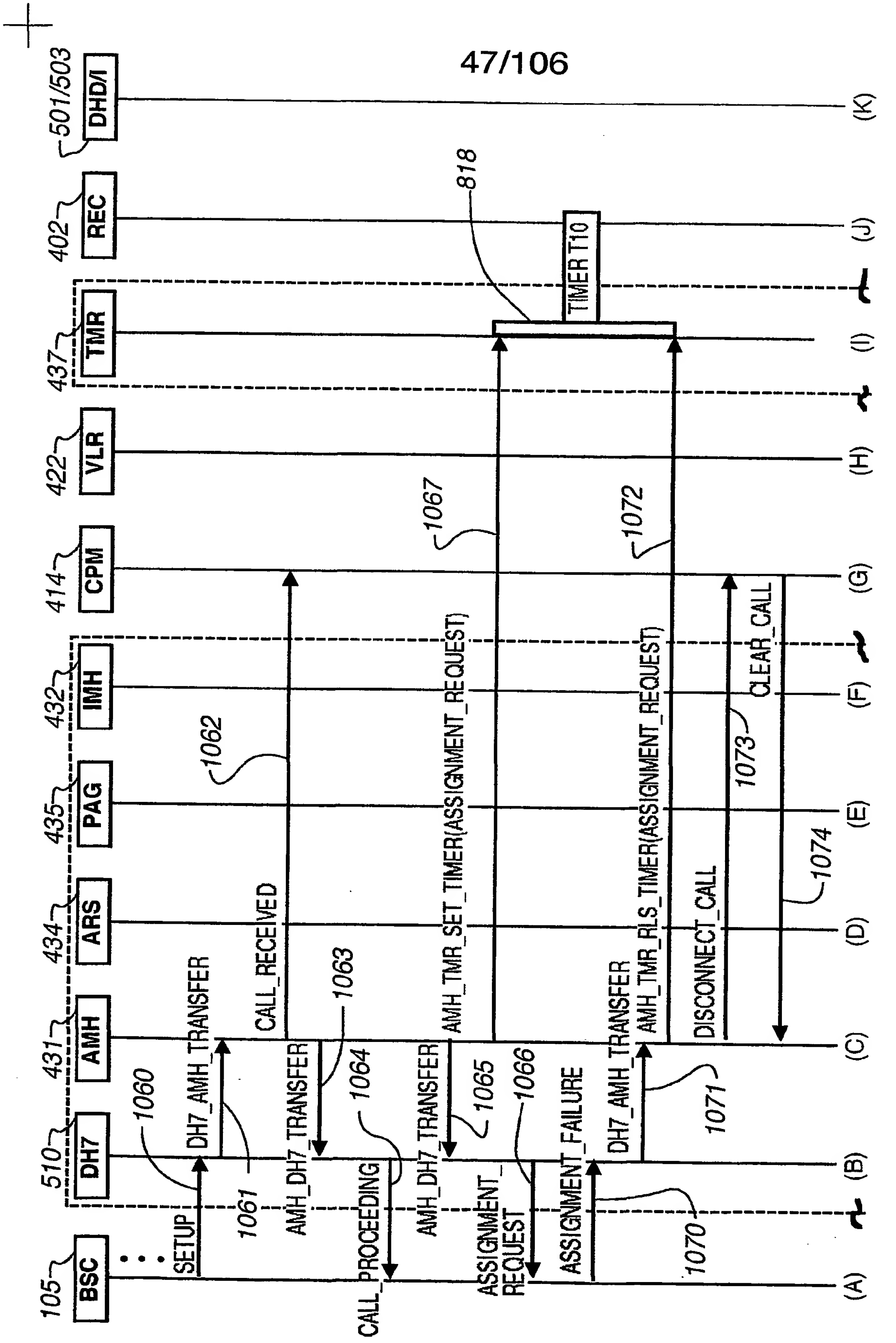

105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
402
REC
501/503
DHD/I
SETUP
1060
DH7_AMH_TRANSFER
1061
CALL_RECEIVED
1062
AMH_DH7_TRANSFER
1063
CALL_PROCEEDING
1064
AMH_DH7_TRANSFER
1065
AMH_TMR_SET_TIMER(ASSIGNMENT_REQUEST)
1067
818
TIMER T10
ASSIGNMENT_REQUEST
1066
ASSIGNMENT_FAILURE
1070
DH7_AMH_TRANSFER
1071
AMH_TMR_RLS_TIMER(ASSIGNMENT_REQUEST)
1072
DISCONNECT_CALL
1073
CLEAR_CALL
1074
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)

Fig. 55A

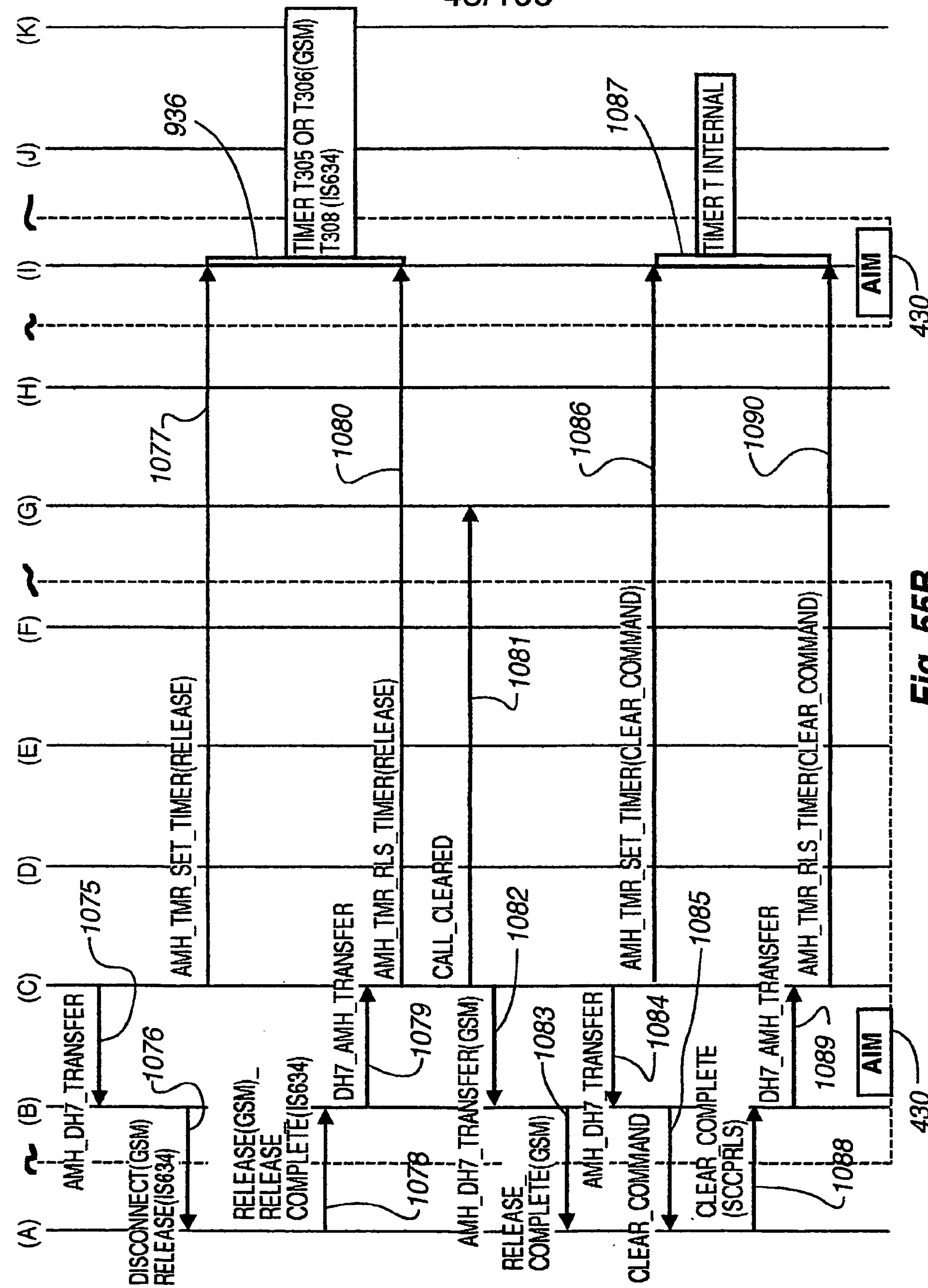
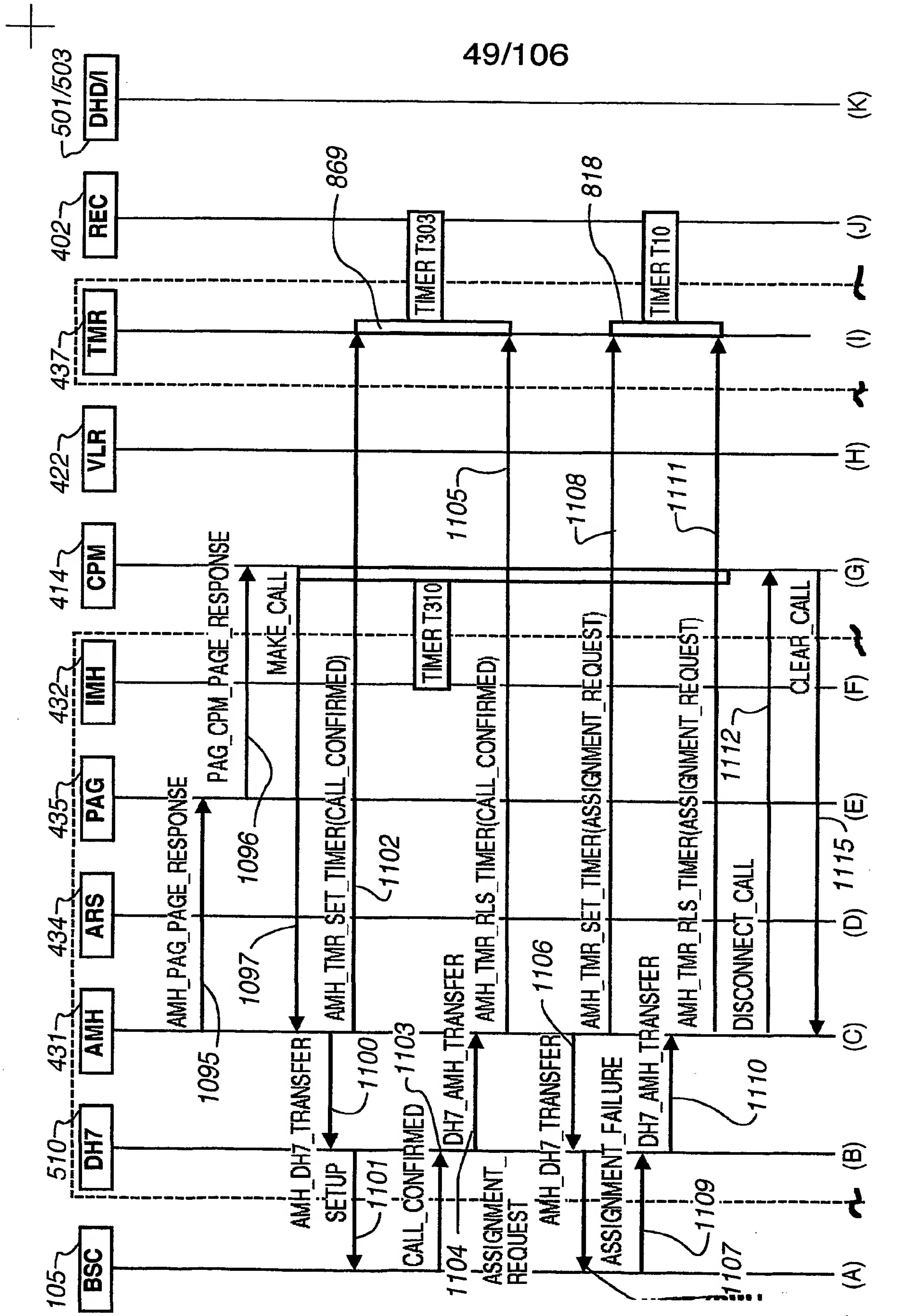
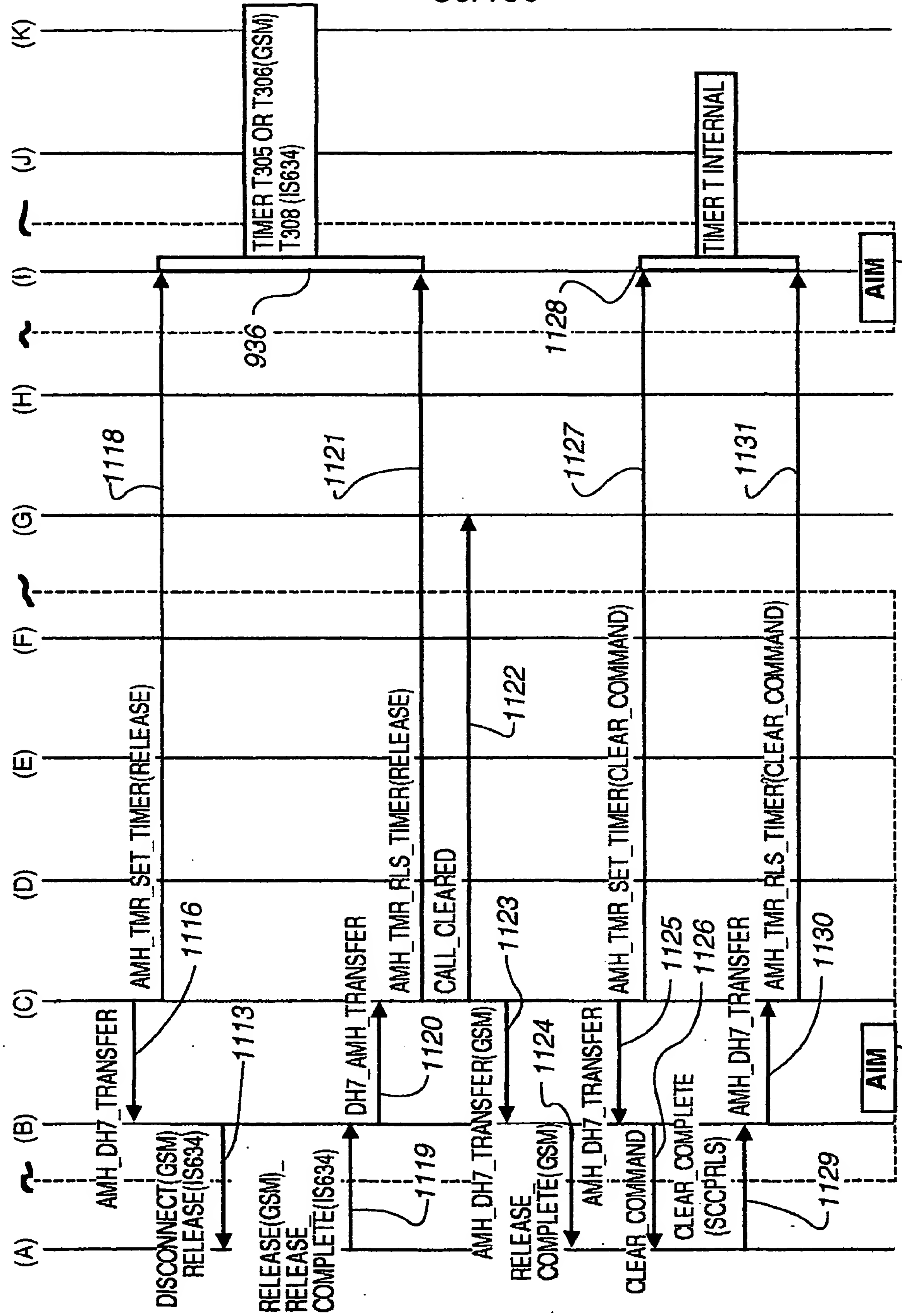

(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
936
TIMER T305 OR T306(GSM)
T308 (IS634)
1087
TIMER T INTERNAL
AIM
430
1077
1080
1086
1090
1081
1075
AMH_DH7_TRANSFER
1076
DISCONNECT(GSM)
RELEASE(IS634)
AMH_TMR_SET_TIMER(RELEASE)
RELEASE(GSM)_
RELEASE
COMPLETE(IS634)
1078
DH7_AMH_TRANSFER
1079
AMH_TMR_RLS_TIMER(RELEASE)
CALL_CLEARED
AMH_DH7_TRANSFER(GSM)
1082
RELEASE_
COMPLETE(GSM)
1083
AMH_DH7_TRANSFER
1084
CLEAR_COMMAND
AMH_TMR_SET_TIMER(CLEAR_COMMAND)
1085
CLEAR_COMPLETE
(SCCPRLS)
1088
DH7_AMH_TRANSFER
1089
AMH_TMR_RLS_TIMER(CLEAR_COMMAND)

Fig. 55B



105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
402
REC
501/503
DHD/I
1095
AMH_PAG_PAGE_RESPONSE
1096
PAG_CPM_PAGE_RESPONSE
MAKE_CALL
1097
AMH_DH7_TRANSFER
SETUP
1100
1101
AMH_TMR_SET_TIMER(CALL_CONFIRMED)
1102
869
TIMER T303
TIMER T310
CALL_CONFIRMED
1103
DH7_AMH_TRANSFER
1104
AMH_TMR_RLS_TIMER(CALL_CONFIRMED)
1105
ASSIGNMENT_REQUEST
AMH_DH7_TRANSFER
1106
AMH_TMR_SET_TIMER(ASSIGNMENT_REQUEST)
1108
818
TIMER T10
ASSIGNMENT_FAILURE
1107
1109
DH7_AMH_TRANSFER
1110
AMH_TMR_RLS_TIMER(ASSIGNMENT_REQUEST)
1111
DISCONNECT_CALL
1112
CLEAR_CALL
1115
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)

Fig. 56A



(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
TIMER T305 OR T306(GSM)
T308 (IS634)
TIMER T INTERNAL
936
1128
AIM
430
1118
1121
1127
1131
AMH_TMR_SET_TIMER(RELEASE)
AMH_TMR_RLS_TIMER(RELEASE)
CALL_CLEARED
1122
AMH_TMR_SET_TIMER(CLEAR_COMMAND)
AMH_TMR_RLS_TIMER(CLEAR_COMMAND)
1116
AMH_DH7_TRANSFER
1113
DISCONNECT(GSM)
RELEASE(IS634)
DH7_AMH_TRANSFER
1120
RELEASE(GSM)_
RELEASE_
COMPLETE(IS634)
1119
AMH_DH7_TRANSFER(GSM)
1123
1124
AMH_DH7_TRANSFER
RELEASE_
COMPLETE(GSM)
AMH_DH7_TRANSFER
1125
1126
CLEAR_COMMAND
CLEAR_COMPLETE
(SCCPRLS)
DH7_AMH_TRANSFER
AMH_DH7_TRANSFER
1130
1129
AIM
430

Fig. 56B

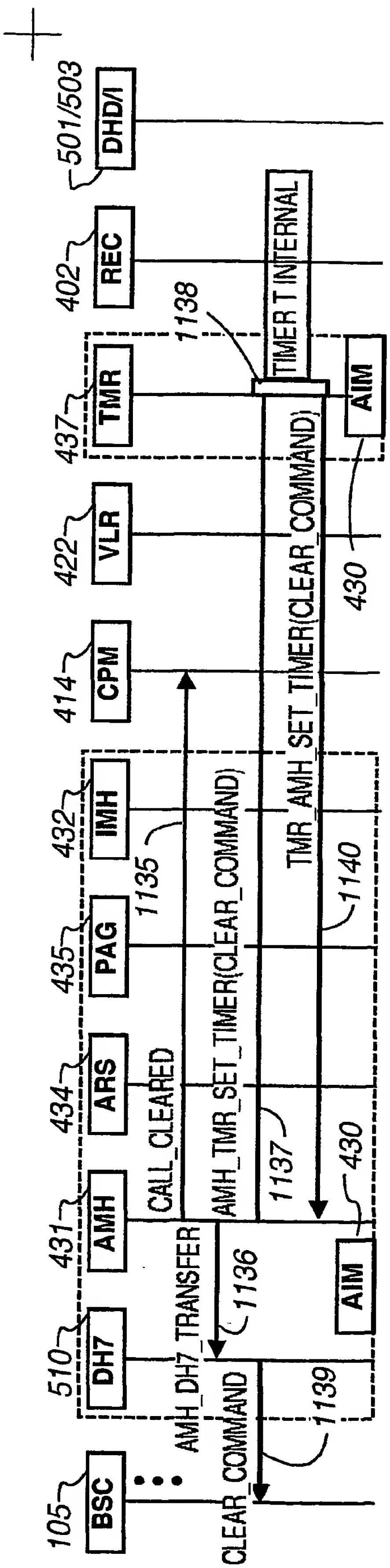

105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
402
REC
501/503
DHD/I
AIM
AIM
430
430
CALL_CLEARED
1135
AMH_DH7_TRANSFER
1136
AMH_TMR_SET_TIMER(CLEAR_COMMAND)
1137
TMR_AMH_SET_TIMER(CLEAR_COMMAND)
1140
TIMER T INTERNAL
1138
CLEAR_COMMAND
1139

Fig. 57

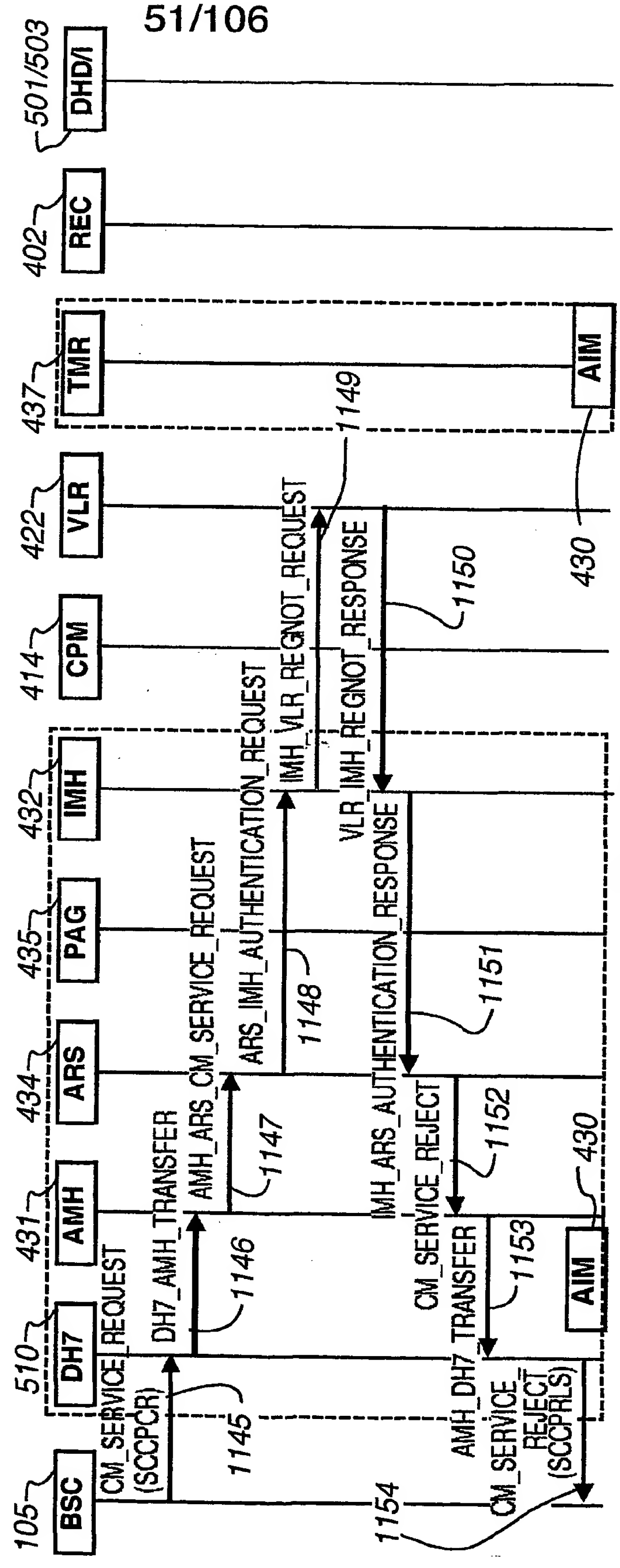

105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
402
REC
501/503
DHD/I
AIM
AIM
430
430
CM_SERVICE_REQUEST (SCCPCR)
1145
DH7_AMH_TRANSFER
1146
AMH_ARS_CM_SERVICE_REQUEST
1147
ARS_IMH_AUTHENTICATION_REQUEST
1148
IMH_VLR_REGNOT_REQUEST
1149
VLR_IMH_REGNOT_RESPONSE
1150
IMH_ARS_AUTHENTICATION_RESPONSE
1151
CM_SERVICE_REJECT
1152
AMH_DH7_TRANSFER
1153
CM_SERVICE_REJECT (SCCPRLS)
1154

Fig. 58

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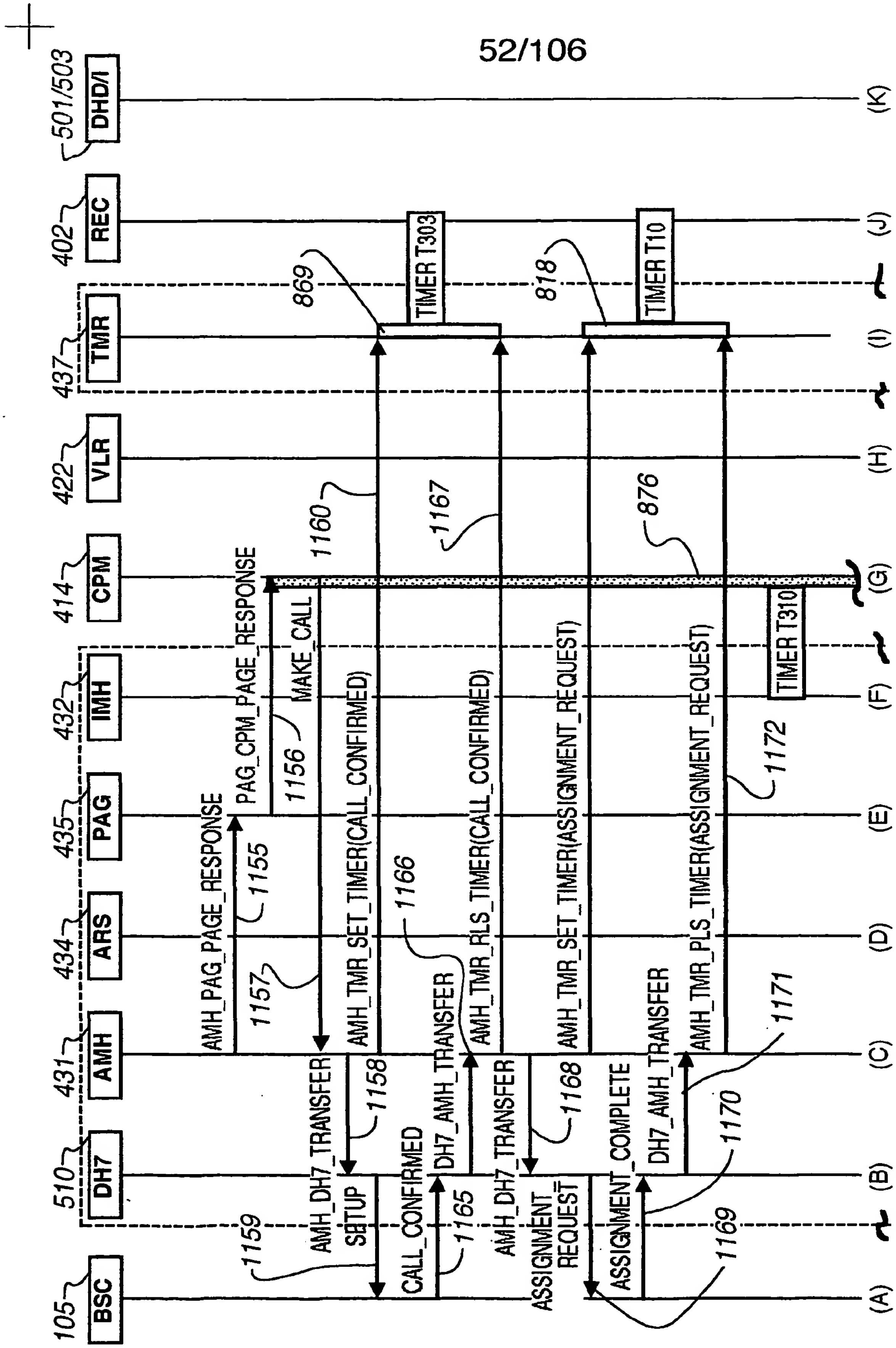

Fig. 59A

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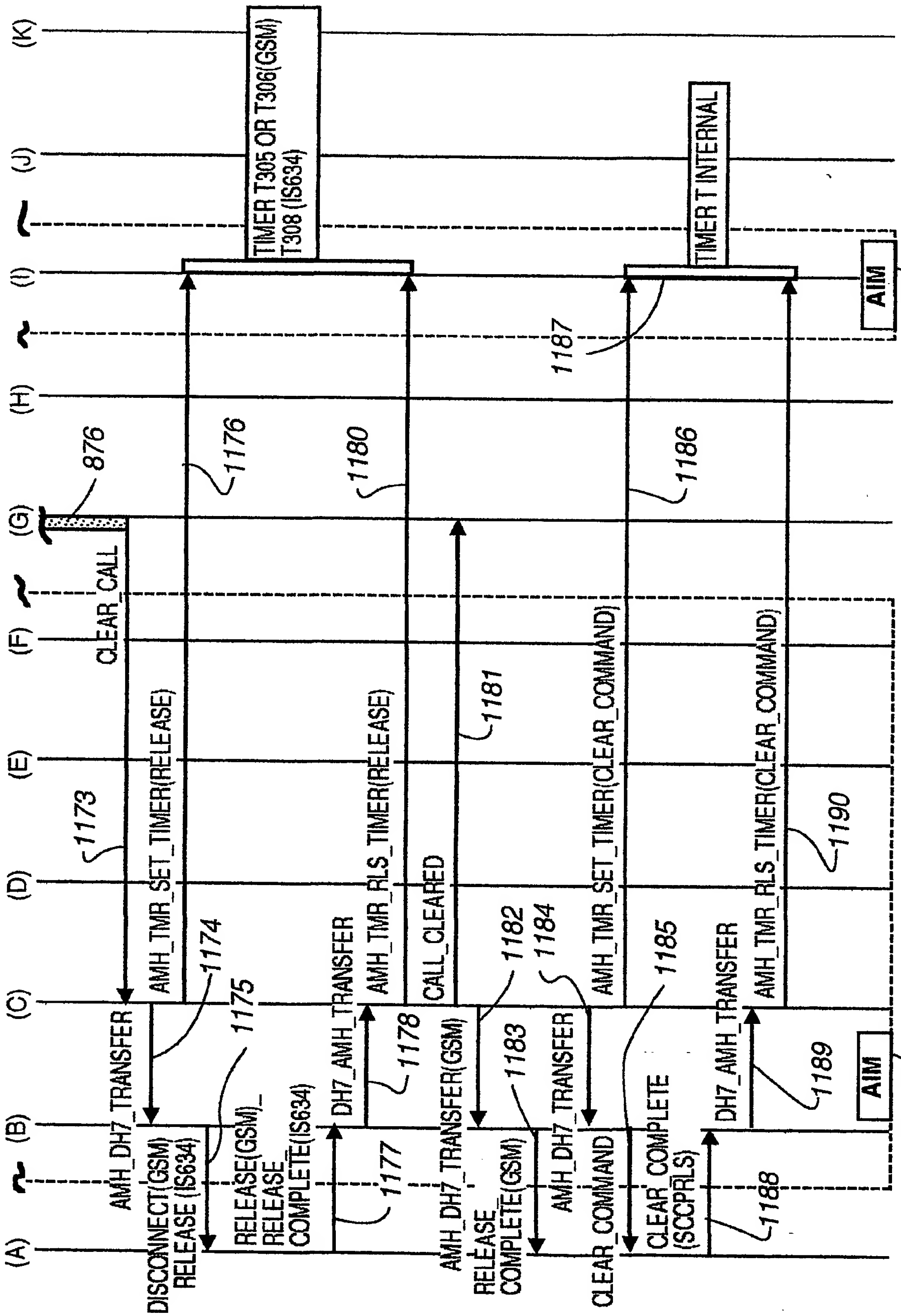


Fig. 59B

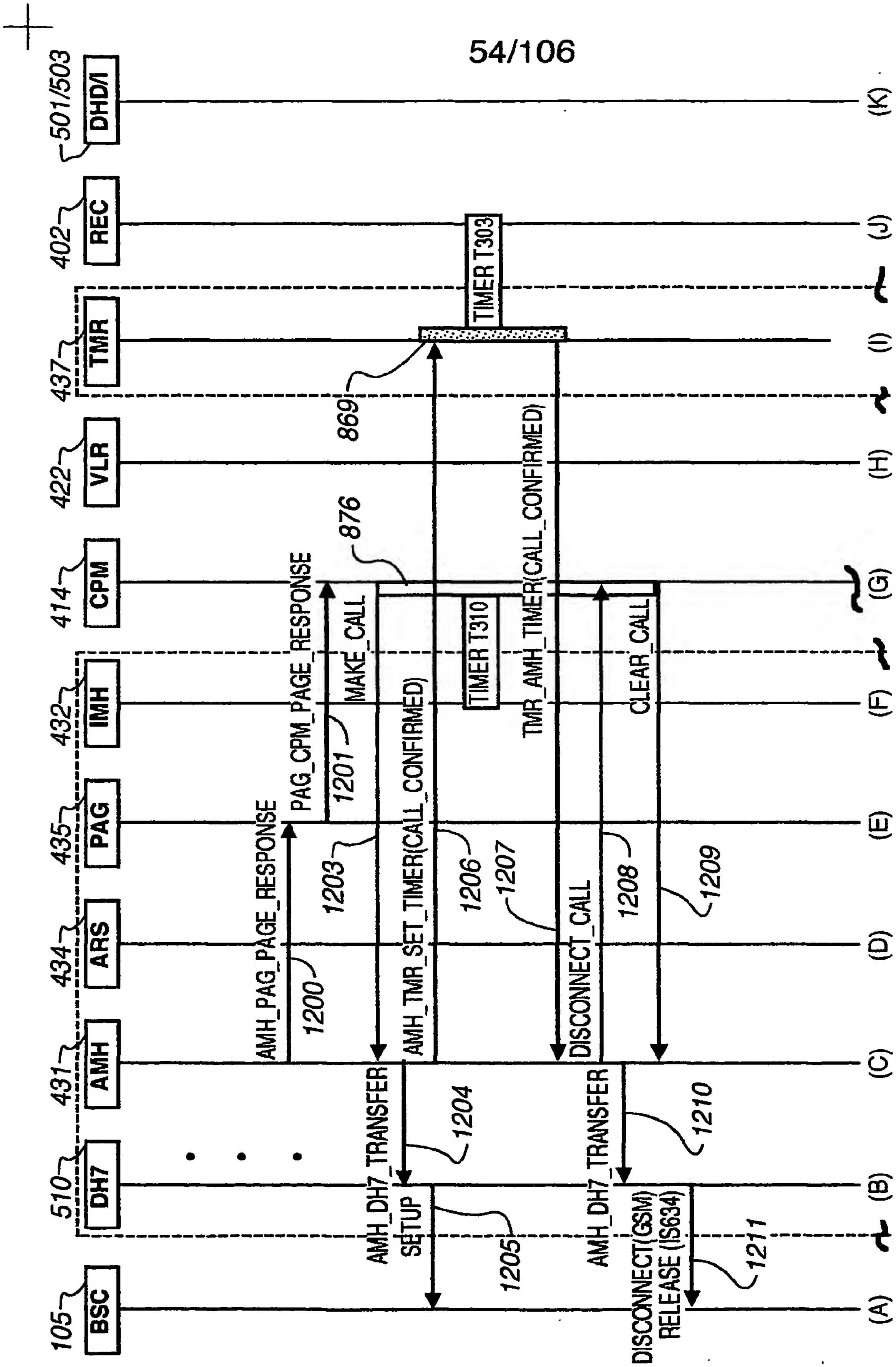
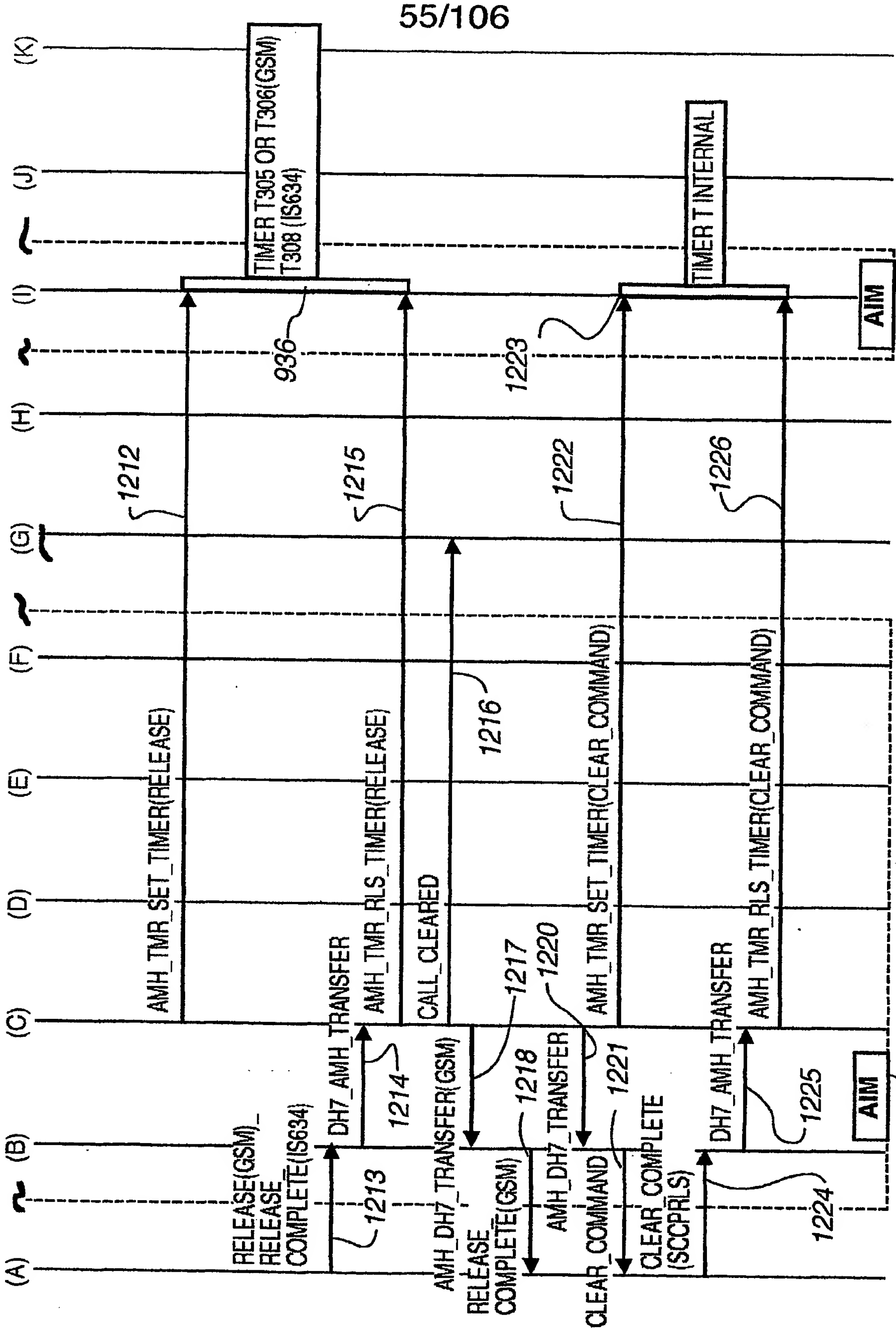
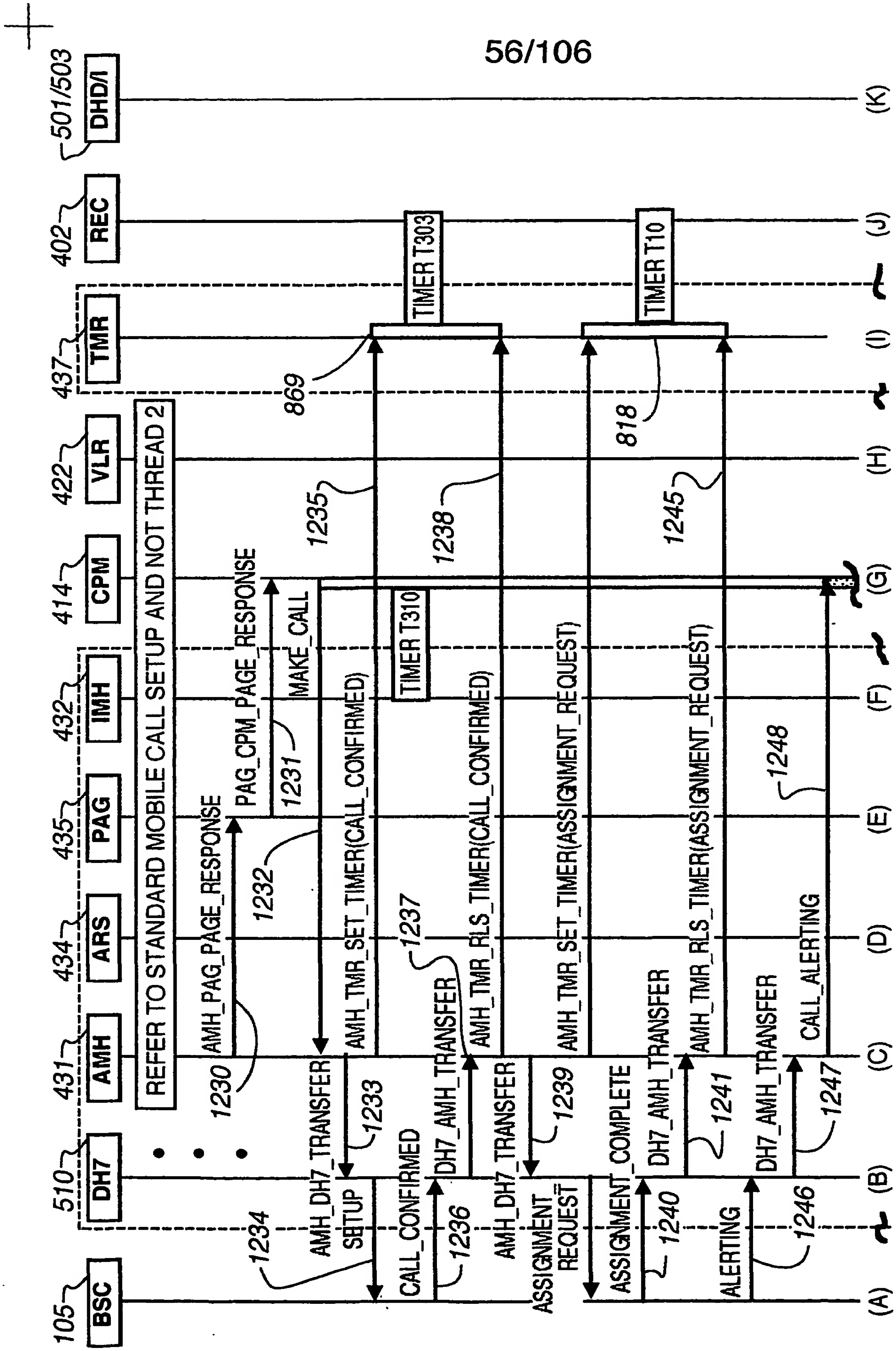

105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
402
REC
501/503
DHD/I
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
AMH_PAG_PAGE_RESPONSE
1200
PAG_CPM_PAGE_RESPONSE
1201
MAKE_CALL
1203
876
AMH_DH7_TRANSFER
1204
SETUP
1205
AMH_TMR_SET_TIMER(CALL_CONFIRMED)
1206
869
TIMER T303
TIMER T310
TMR_AMH_TIMER(CALL_CONFIRMED)
1207
DISCONNECT_CALL
1208
CLEAR_CALL
1209
AMH_DH7_TRANSFER
1210
DISCONNECT(GSM)
RELEASE (IS634)
1211

Fig. 60A



(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
TIMER T305 OR T306(GSM) T308 (IS634)
TIMER T INTERNAL
AIM
430
936
1223
1212
1215
1222
1226
1216
AMH_TMR_SET_TIMER(RELEASE)
AMH_TMR_RLS_TIMER(RELEASE)
CALL_CLEARED
AMH_TMR_SET_TIMER(CLEAR_COMMAND)
AMH_TMR_RLS_TIMER(CLEAR_COMMAND)
AMH_TRANSFER
DH7_AMH_TRANSFER
1217
1220
1214
AMH_DH7_TRANSFER(GSM)
1218
AMH_DH7_TRANSFER
1221
DH7_AMH_TRANSFER
1225
RELEASE(GSM)_ RELEASE COMPLETE(IS634)
1213
AMH_DH7_TRANSFER RELEASE COMPLETE(GSM)
CLEAR_COMMAND
CLEAR_COMPLETE (SCCPRLS)
1224
AIM
430

Fig. 60B



105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
402 REC
501/503 DHD/I
REFER TO STANDARD MOBILE CALL SETUP AND NOT THREAD 2
1230 AMH_PAG_PAGE_RESPONSE
PAG_CPM_PAGE_RESPONSE
1231
MAKE_CALL
1232
AMH_DH7_TRANSFER
1233
1234
AMH_DH7_SETUP
AMH_TMR_SET_TIMER(CALL_CONFIRMED)
1235
869
TIMER T303
TIMER T310
CALL_CONFIRMED
1236
DH7_AMH_TRANSFER
1237
AMH_TMR_RLS_TIMER(CALL_CONFIRMED)
1238
AMH_DH7_TRANSFER
1239
AMH_DH7_ASSIGNMENT_REQUEST
AMH_TMR_SET_TIMER(ASSIGNMENT_REQUEST)
818
TIMER T10
ASSIGNMENT_COMPLETE
1240
DH7_AMH_TRANSFER
1241
AMH_TMR_RLS_TIMER(ASSIGNMENT_REQUEST)
1245
ALERTING
1246
DH7_AMH_TRANSFER
1247
CALL_ALERTING
1248
(A) (B) (C) (D) (E) (F) (G) (H) (I) (J) (K)

Fig. 61A

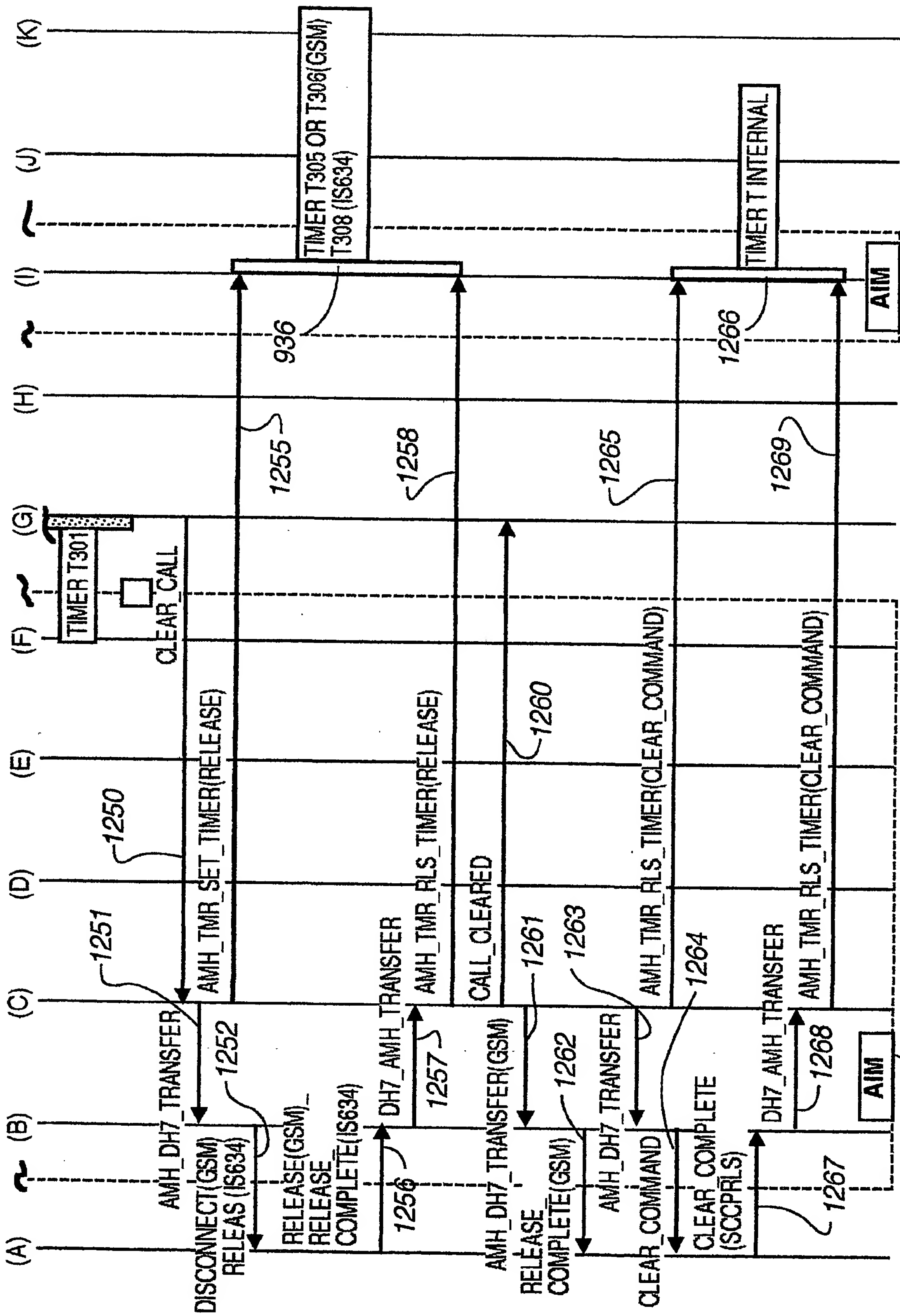

(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
TIMER T305 OR T306(GSM)
T308 (IS634)
TIMER T INTERNAL
TIMER T301
CLEAR_CALL
AIM
430
936
1266
1250
1251
AMH_TMR_SET_TIMER(RELEASE)
AMH_DH7_TRANSFER
1252
DISCONNECT(GSM)
RELEAS (IS634)
1255
RELEASE(GSM)_
RELEASE_
COMPLETE(IS634)
1256
DH7_AMH_TRANSFER
1257
AMH_TMR_RLS_TIMER(RELEASE)
1258
CALL_CLEARED
1260
AMH_DH7_TRANSFER(GSM)
1261
RELEASE_
COMPLETE(GSM)
1262
1263
AMH_DH7_TRANSFER
CLEAR_COMMAND
1264
AMH_TMR_RLS_TIMER(CLEAR_COMMAND)
1265
CLEAR_COMPLETE
(SCCPRLS)
1267
DH7_AMH_TRANSFER
1268
AMH_TMR_RLS_TIMER(CLEAR_COMMAND)
1269

Fig. 61B

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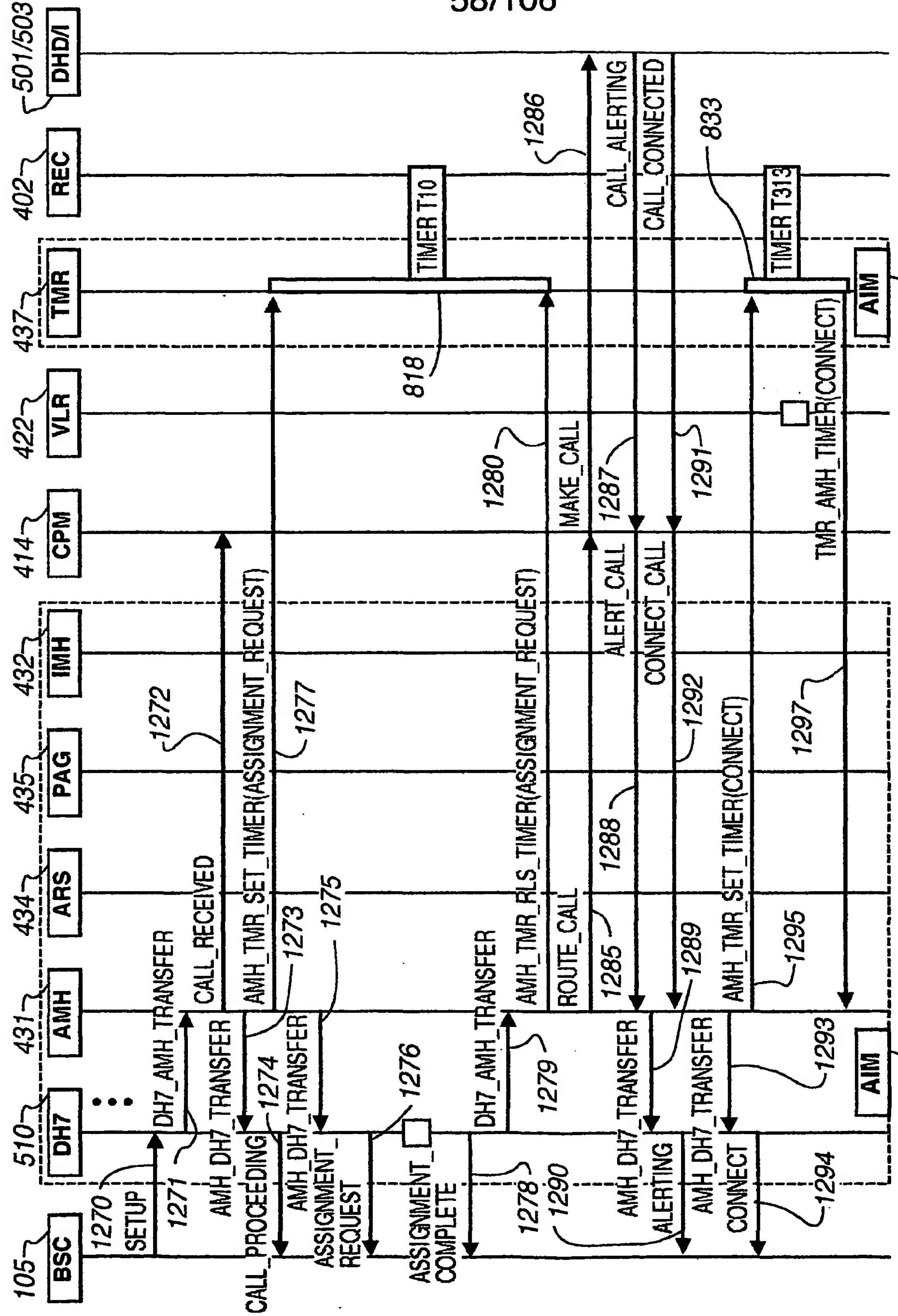
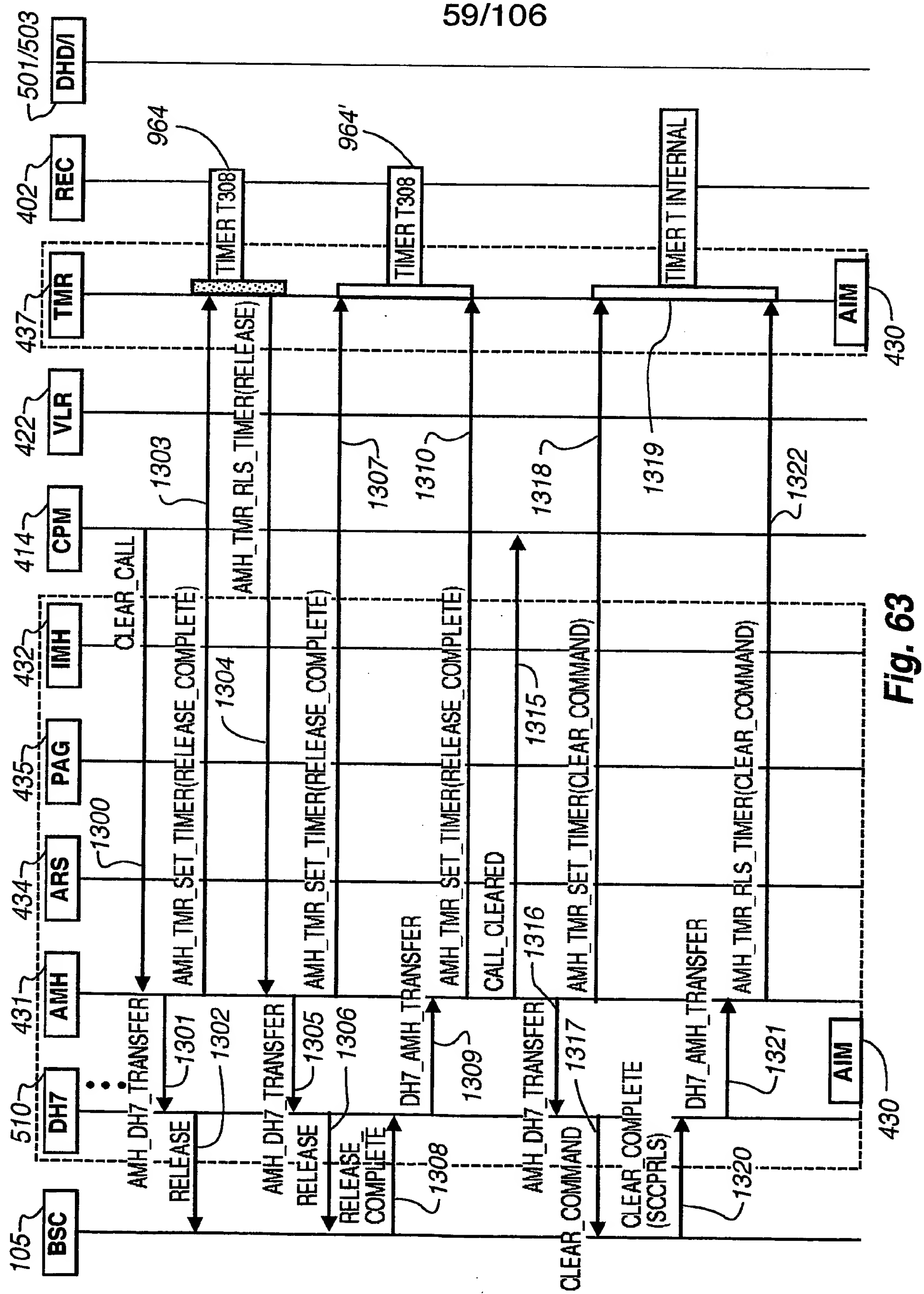

105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
402
REC
501/503
DHD/I
430
AIM
1270
SETUP
1271
DH7_AMH_TRANSFER
AMH_TRANSFER
1272
CALL_RECEIVED
AMH_DH7_TRANSFER
CALL_PROCEEDING
1273
AMH_TMR_SET_TIMER(ASSIGNMENT_REQUEST)
1274
1275
1277
AMH_DH7_TRANSFER
ASSIGNMENT_REQUEST
1276
ASSIGNMENT_COMPLETE
1278
DH7_AMH_TRANSFER
1279
AMH_TRANSFER
AMH_TMR_RLS_TIMER(ASSIGNMENT_REQUEST)
818
TIMER T10
ROUTE_CALL
1280
MAKE_CALL
1285
1286
CALL_ALERTING
1287
ALERT_CALL
1288
AMH_DH7_TRANSFER
1290
ALERTING
CALL_CONNECTED
1291
CONNECT_CALL
1292
1289
AMH_DH7_TRANSFER
CONNECT
1294
1293
AMH_TMR_SET_TIMER(CONNECT)
1295
833
TIMER T313
TMR_AMH_TIMER(CONNECT)
1297

Fig. 62



105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
402 REC
501/503 DHD/I
430 AIM
1300 CLEAR_CALL
AMH_DH7_TRANSFER 1301
RELEASE 1302
1303 AMH_TMR_SET_TIMER(RELEASE_COMPLETE)
964 TIMER T308
1304 AMH_TMR_RLS_TIMER(RELEASE)
AMH_DH7_TRANSFER 1305
RELEASE 1306
1307 AMH_TMR_SET_TIMER(RELEASE_COMPLETE)
964' TIMER T308
RELEASE_COMPLETE 1308
DH7_AMH_TRANSFER 1309
1310 AMH_TMR_SET_TIMER(RELEASE_COMPLETE)
CALL_CLEARED 1315
1316 AMH_DH7_TRANSFER
CLEAR_COMMAND 1317
1318 AMH_TMR_SET_TIMER(CLEAR_COMMAND)
1319 TIMER T INTERNAL
CLEAR_COMPLETE (SCCPRLS) 1320
DH7_AMH_TRANSFER 1321
1322 AMH_TMR_RLS_TIMER(CLEAR_COMMAND)

Fig. 63

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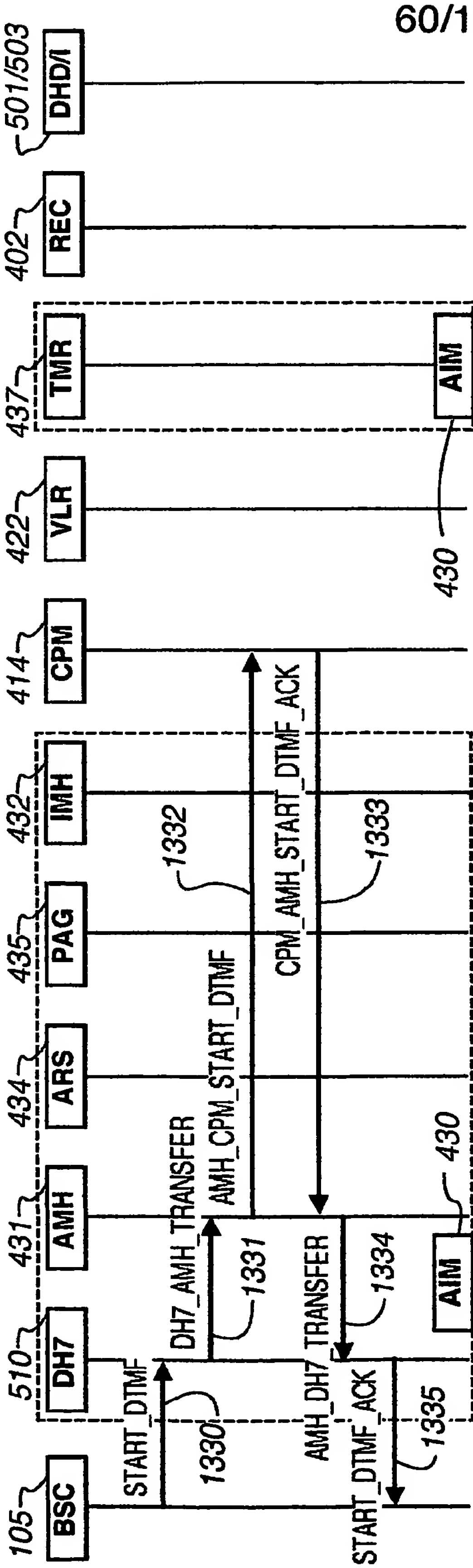


Fig. 64

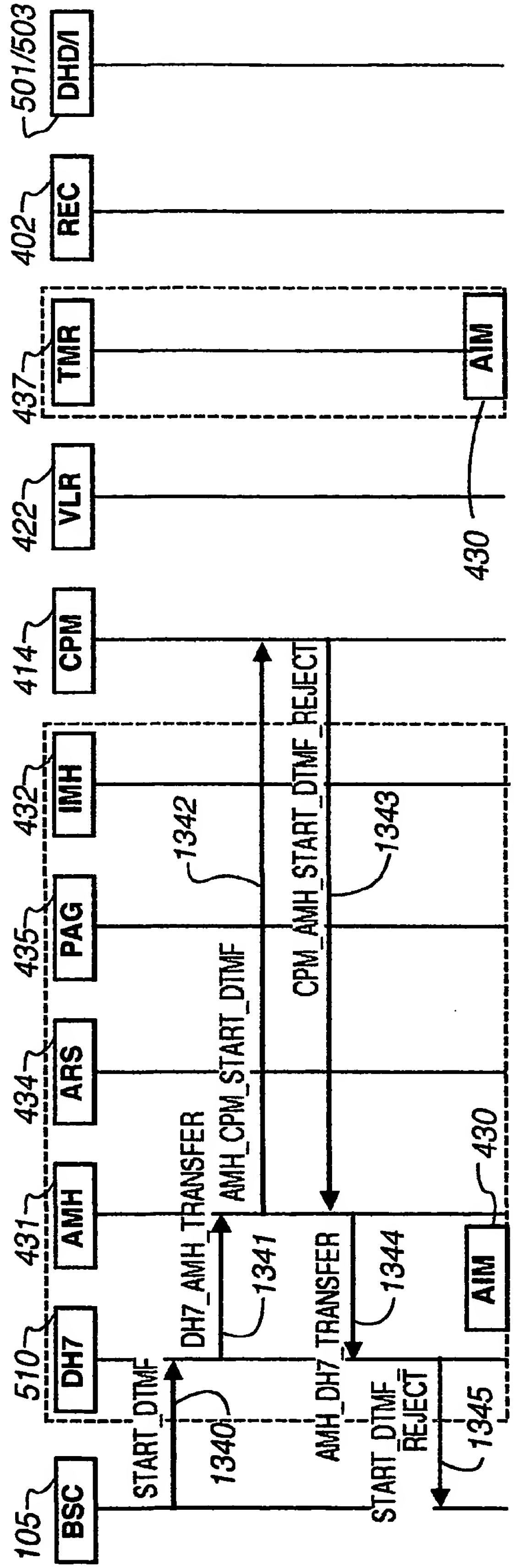
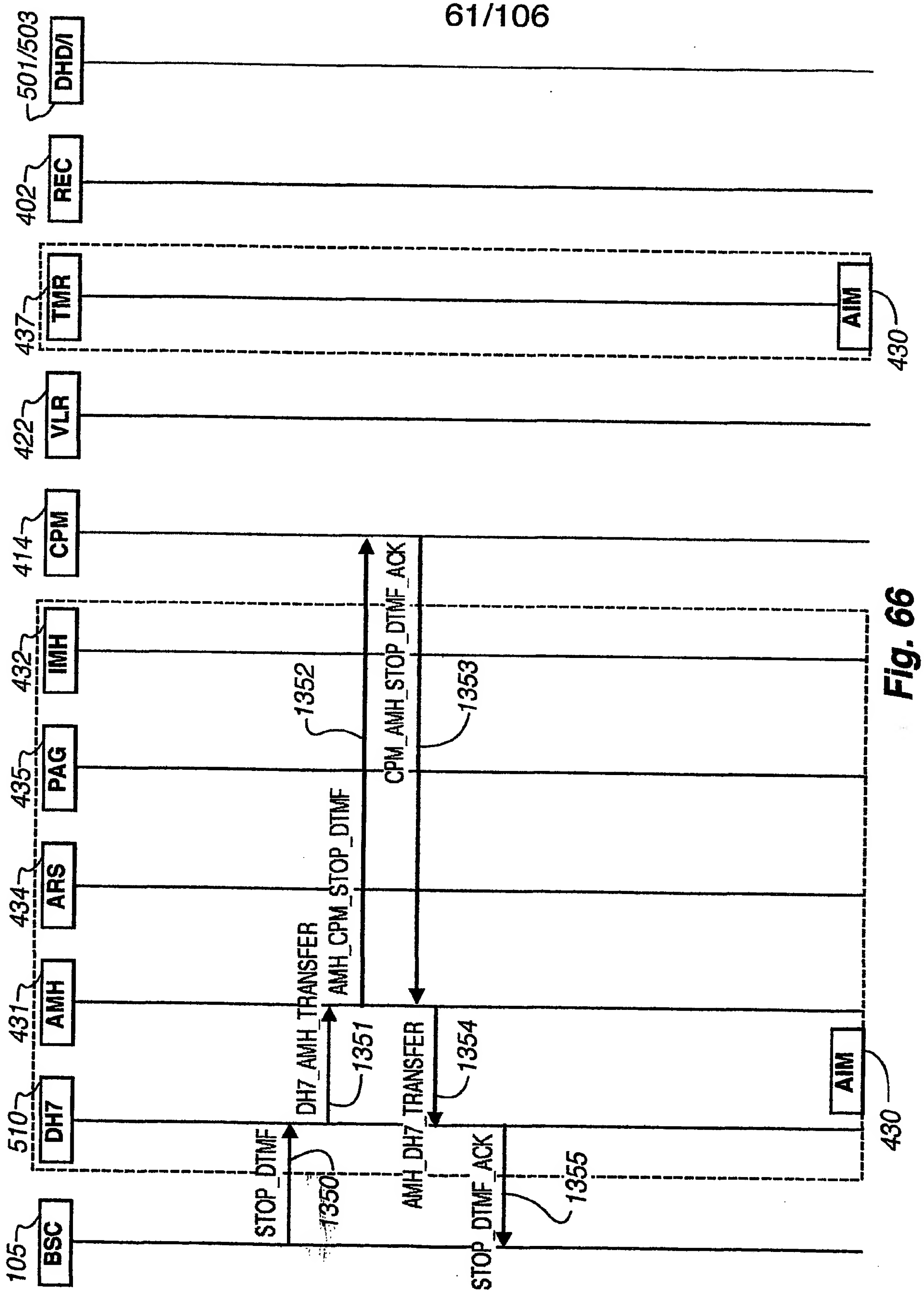


Fig. 65



105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
402
REC
501/503
DHD/I
AIM
430
AIM
430
STOP_DTMF
1350
DH7_AMH_TRANSFER
1351
AMH_CPM_STOP_DTMF
1352
CPM_AMH_STOP_DTMF_ACK
1353
AMH_DH7_TRANSFER
1354
STOP_DTMF_ACK
1355

Fig. 66

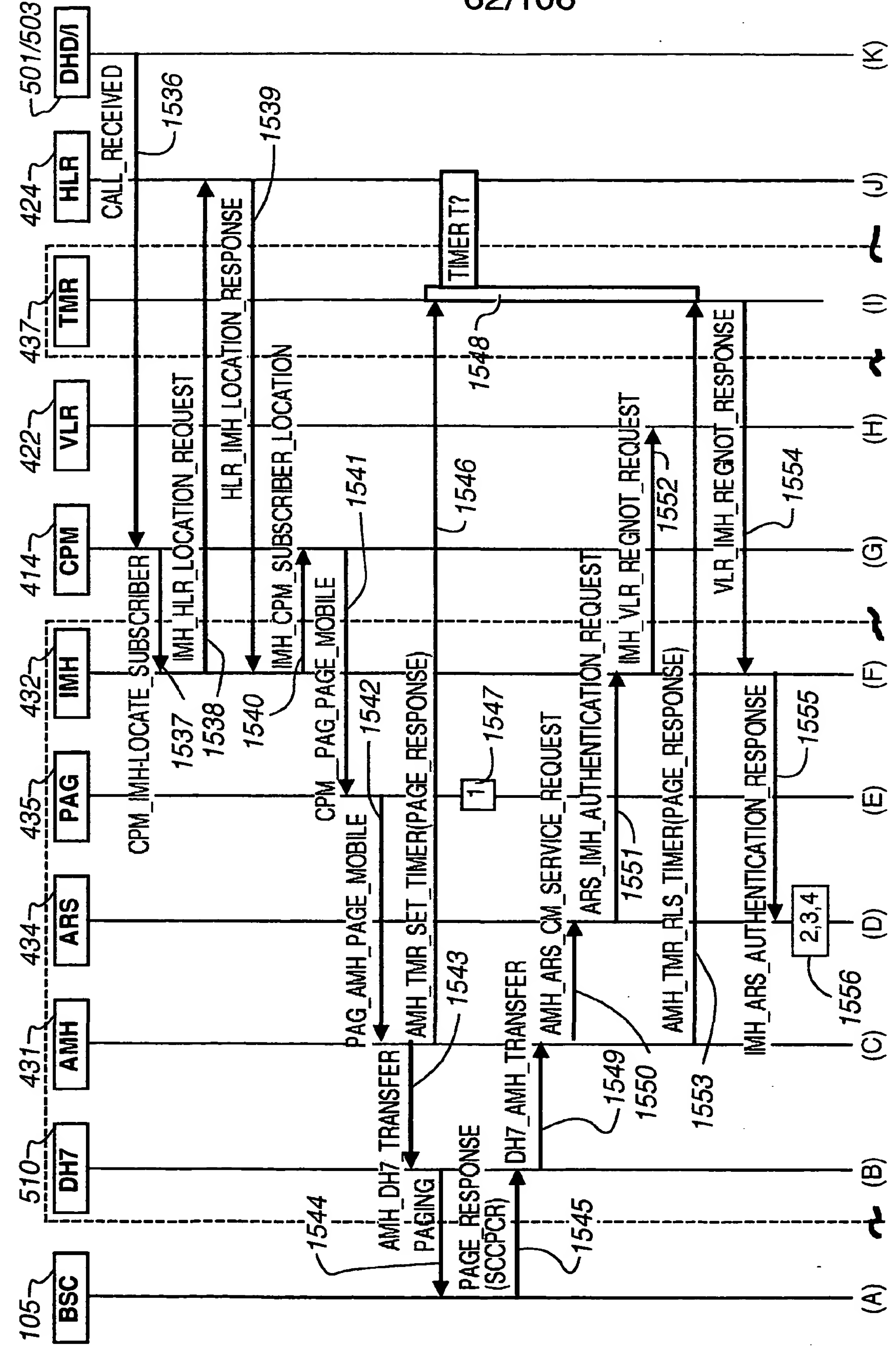

105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
424
HLR
501/503
DHD/I
CALL_RECEIVED
1536
CPM_IMH-LOCATE_SUBSCRIBER
1537
IMH_HLR_LOCATION_REQUEST
1538
HLR_IMH_LOCATION_RESPONSE
1539
IMH_CPM_SUBSCRIBER_LOCATION
1540
CPM_PAG_PAGE_MOBILE
1541
PAG_AMH_PAGE_MOBILE
1542
AMH_DH7_TRANSFER
1543
AMH_DH7 PAGING
1544
PAGE_RESPONSE (SCCPCR)
1545
DH7_AMH_TRANSFER
1549
AMH_TMR_SET_TIMER(PAGE_RESPONSE)
1546
1547
1
TIMER T?
1548
AMH_ARS_CM_SERVICE_REQUEST
1550
ARS_IMH_AUTHENTICATION_REQUEST
1551
IMH_VLR_REGNOT_REQUEST
1552
AMH_TMR_RLS_TIMER(PAGE_RESPONSE)
1553
VLR_IMH_REGNOT_RESPONSE
1554
IMH_ARS_AUTHENTICATION_RESPONSE
1555
2,3,4
1556
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)

Fig. 67A

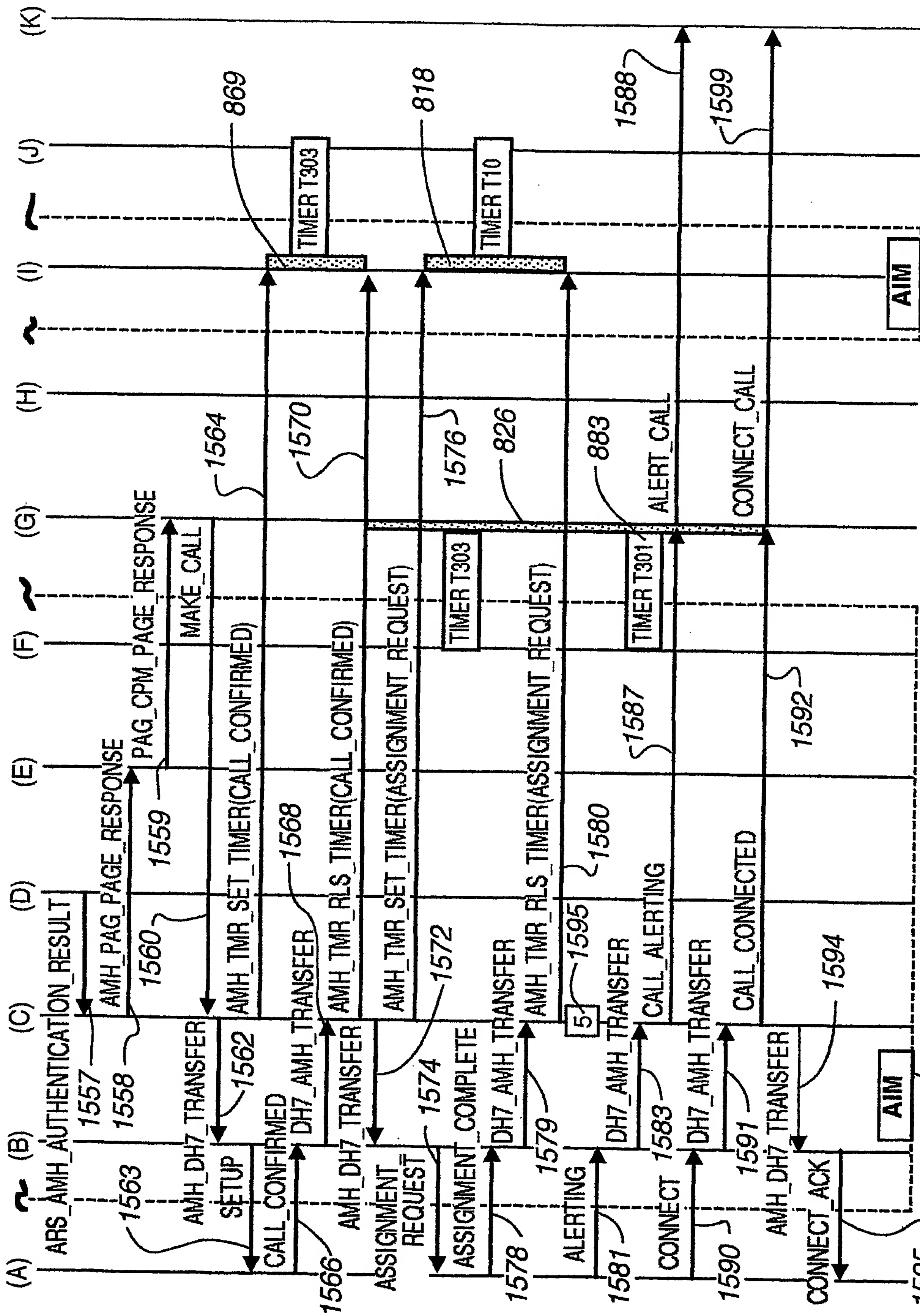

(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
ARS_AMH_AUTHENTICATION_RESULT
1557
AMH_PAG_PAGE_RESPONSE
1558
1560
PAG_PAGE_RESPONSE
1559
PAG_CPM_PAGE_RESPONSE
MAKE_CALL
AMH_DH7_TRANSFER
1562
SETUP
1563
CALL_CONFIRMED
1566
DH7_AMH_TRANSFER
AMH_TMR_SET_TIMER(CALL_CONFIRMED)
1564
869
TIMER T303
1568
AMH_TMR_RLS_TIMER(CALL_CONFIRMED)
1570
AMH_DH7_TRANSFER
ASSIGNMENT_REQUEST
1572
AMH_TMR_SET_TIMER(ASSIGNMENT_REQUEST)
1576
818
TIMER T10
826
TIMER T303
1574
ASSIGNMENT_COMPLETE
1578
DH7_AMH_TRANSFER
1579
AMH_TMR_RLS_TIMER(ASSIGNMENT_REQUEST)
1580
5
1595
ALERTING
1581
DH7_AMH_TRANSFER
1583
CALL_ALERTING
1587
883
TIMER T301
ALERT_CALL
1588
CONNECT
1590
DH7_AMH_TRANSFER
1591
CALL_CONNECTED
1592
CONNECT_CALL
1599
AMH_DH7_TRANSFER
1594
CONNECT_ACK
1595
AIM
430
AIM
430

Fig. 67B

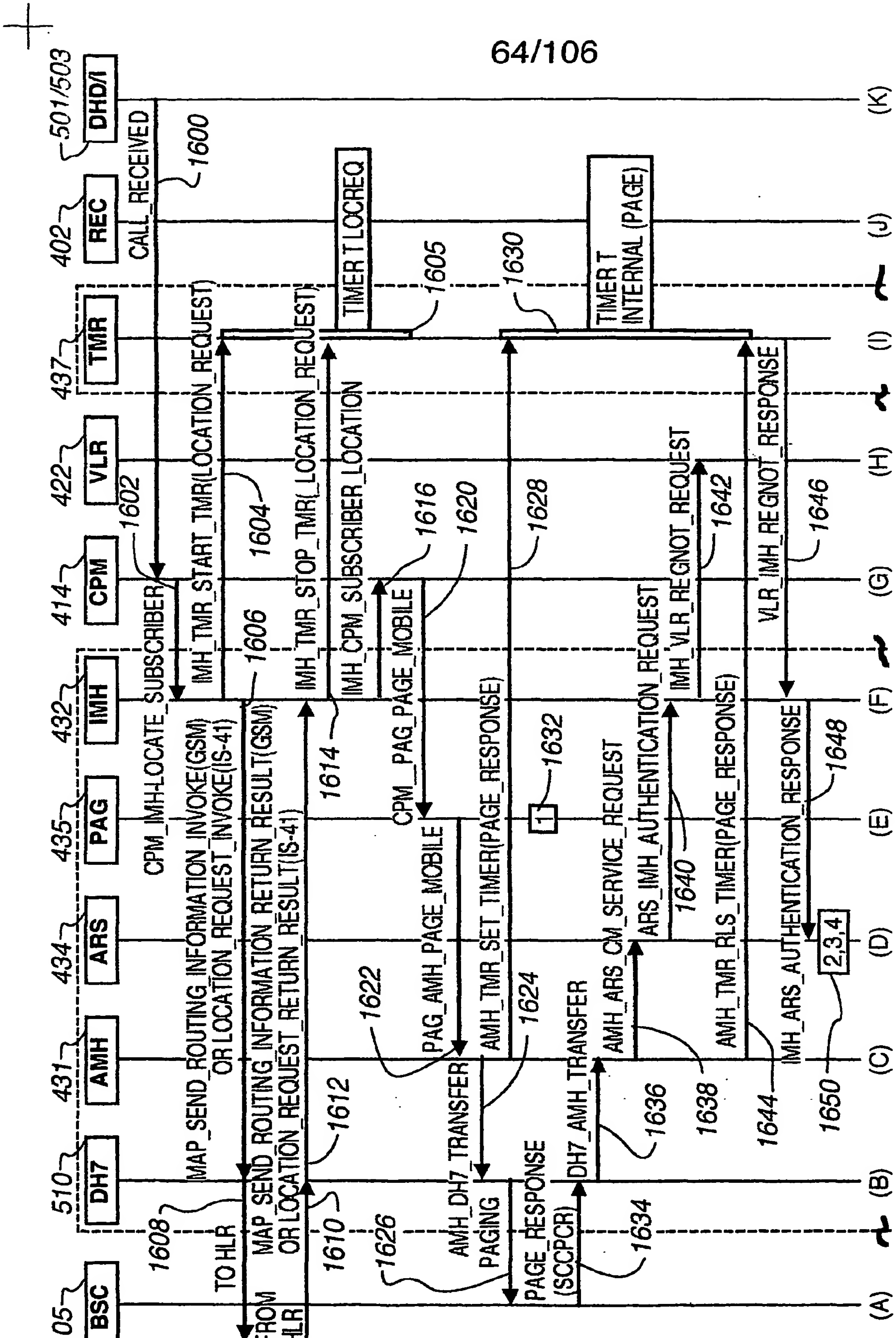

105 BSC
510 DH7
431 AMH
434 ARS
435 PAG
432 IMH
414 CPM
422 VLR
437 TMR
402 REC
501/503 DHD/I
CALL_RECEIVED
1600
1602
CPM_IMH-LOCATE_SUBSCRIBER
IMH_TMR_START_TMR(LOCATION_REQUEST)
1604
TIMER T LOCREQ
1605
1606
MAP_SEND_ROUTING_INFORMATION_INVOKE(GSM)
OR LOCATION_REQUEST_INVOKE(IS-41)
1608
TO HLR
MAP_SEND_ROUTING_INFORMATION_RETURN_RESULT(GSM)
OR LOCATION_REQUEST_RETURN_RESULT(IS-41)
FROM HLR
1610
1612
IMH_TMR_STOP_TMR(LOCATION_REQUEST)
1614
IMH_CPM_SUBSCRIBER_LOCATION
1616
CPM_PAG_PAGE_MOBILE
1620
PAG_AMH_PAGE_MOBILE
1622
AMH_DH7_TRANSFER
PAGING
1626
AMH_TMR_SET_TIMER(PAGE_RESPONSE)
1624
1628
1630
TIMER T INTERNAL (PAGE)
1
1632
PAGE_RESPONSE (SCCPCR)
1634
DH7_AMH_TRANSFER
1636
AMH_ARS_CM_SERVICE_REQUEST
1638
ARS_IMH_AUTHENTICATION_REQUEST
1640
IMH_VLR_REGNOT_REQUEST
1642
AMH_TMR_RLS_TIMER(PAGE_RESPONSE)
1644
VLR_IMH_REGNOT_RESPONSE
1646
IMH_ARS_AUTHENTICATION_RESPONSE
1648
2,3,4
1650
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)

Fig. 68A

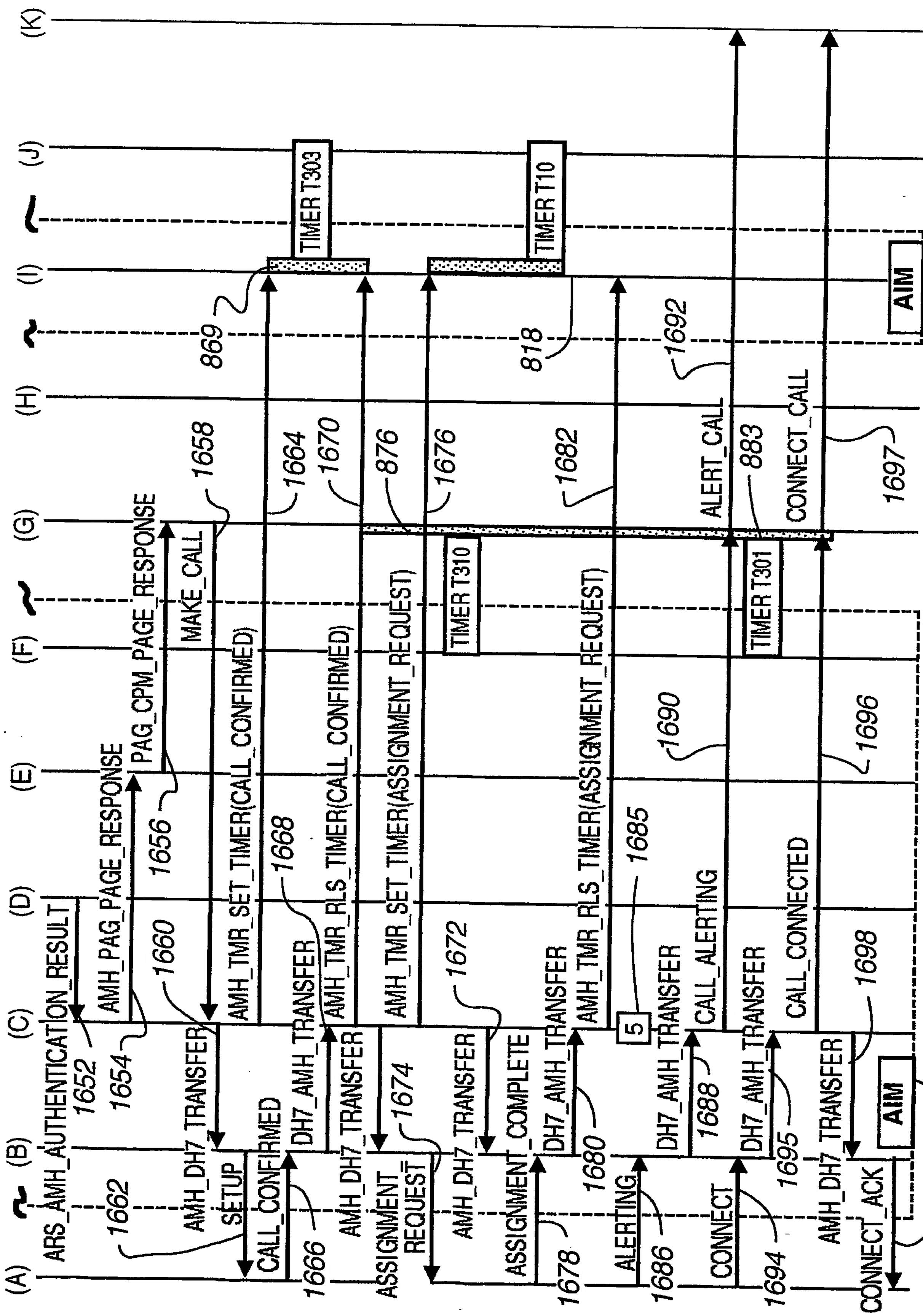

(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
ARS_AMH_AUTHENTICATION_RESULT
AMH_PAG_PAGE_RESPONSE
PAG_CPM_PAGE_RESPONSE
MAKE_CALL
AMH_DH7_TRANSFER
SETUP
AMH_TMR_SET_TIMER(CALL_CONFIRMED)
CALL_CONFIRMED
DH7_AMH_TRANSFER
AMH_TMR_RLS_TIMER(CALL_CONFIRMED)
AMH_DH7_TRANSFER
ASSIGNMENT_REQUEST
AMH_TMR_SET_TIMER(ASSIGNMENT_REQUEST)
AMH_DH7_TRANSFER
ASSIGNMENT_COMPLETE
DH7_AMH_TRANSFER
AMH_TMR_RLS_TIMER(ASSIGNMENT_REQUEST)
ALERTING
DH7_AMH_TRANSFER
CALL_ALERTING
ALERT_CALL
CONNECT
DH7_AMH_TRANSFER
CALL_CONNECTED
CONNECT_CALL
AMH_DH7_TRANSFER
CONNECT_ACK
TIMER T303
TIMER T10
TIMER T310
TIMER T301
AIM
AIM
5
1652
1654
1656
1658
1660
1662
1664
1666
1668
1670
1672
1674
1676
1678
1680
1682
1685
1686
1688
1690
1692
1694
1695
1696
1697
1698
1699
869
818
876
883
430
430

Fig. 68B

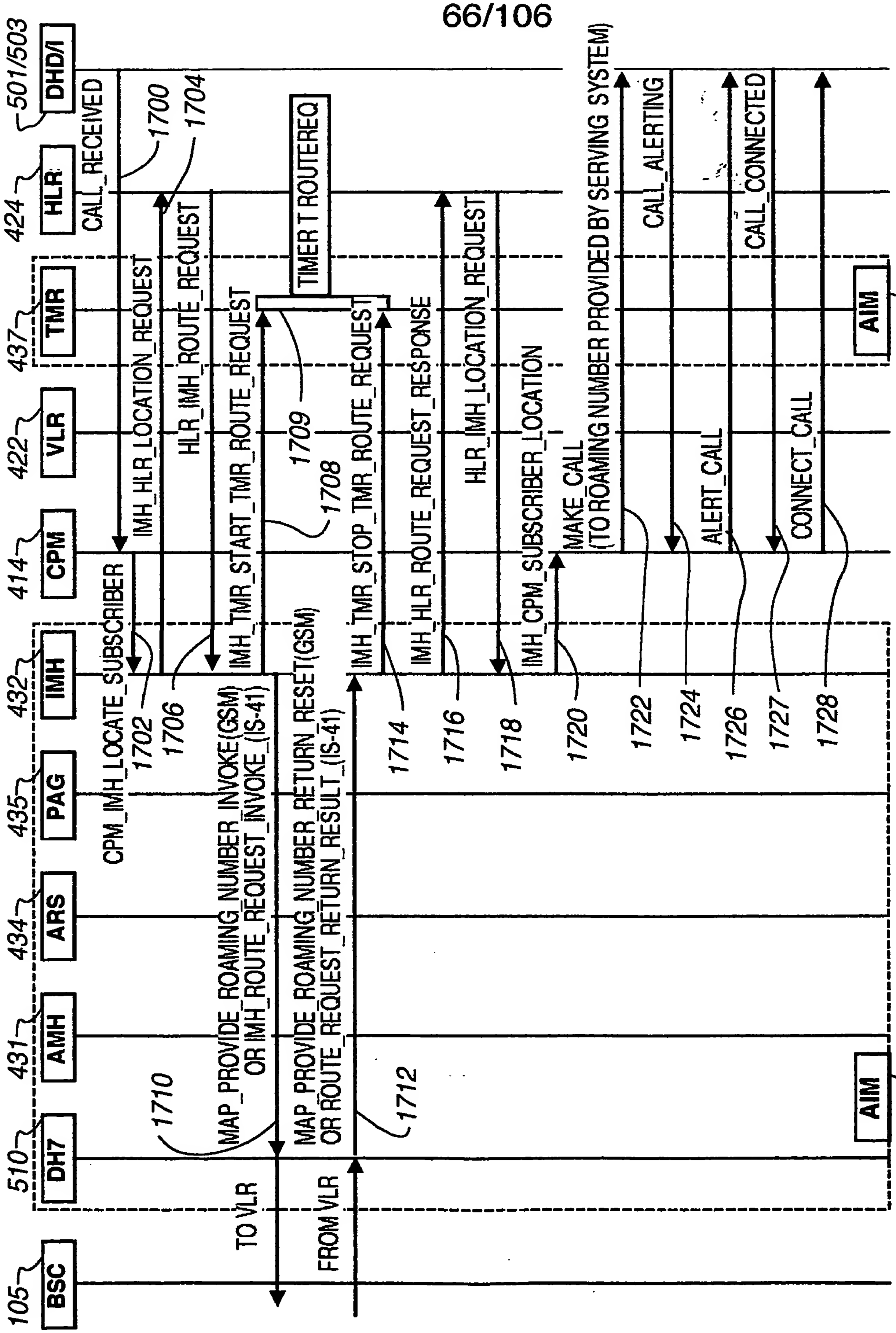

501/503
DHD/I
424
HLR
437
TMR
422
VLR
414
CPM
432
IMH
435
PAG
434
ARS
431
AMH
510
DH7
105
BSC
430
AIM
AIM
430
CALL_RECEIVED
1700
1704
IMH_HLR_LOCATION_REQUEST
HLR_IMH_ROUTE_REQUEST
CPM_IMH_LOCATE_SUBSCRIBER
1702
1706
IMH_TMR_START_TMR_ROUTE_REQUEST
TIMER T ROUTEREQ
1709
1708
MAP_PROVIDE_ROAMING_NUMBER_INVOKE(GSM)
OR IMH_ROUTE_REQUEST_INVOKE_(IS-41)
1710
TO VLR
MAP_PROVIDE_ROAMING_NUMBER_RETURN_RESET(GSM)
OR ROUTE_REQUEST_RETURN_RESULT_(IS-41)
1712
FROM VLR
IMH_TMR_STOP_TMR_ROUTE_REQUEST
1714
IMH_HLR_ROUTE_REQUEST_RESPONSE
1716
HLR_IMH_LOCATION_REQUEST
1718
IMH_CPM_SUBSCRIBER_LOCATION
1720
MAKE_CALL
(TO ROAMING NUMBER PROVIDED BY SERVING SYSTEM)
1722
CALL_ALERTING
1724
ALERT_CALL
1726
CALL_CONNECTED
1727
CONNECT_CALL
1728

Fig. 69

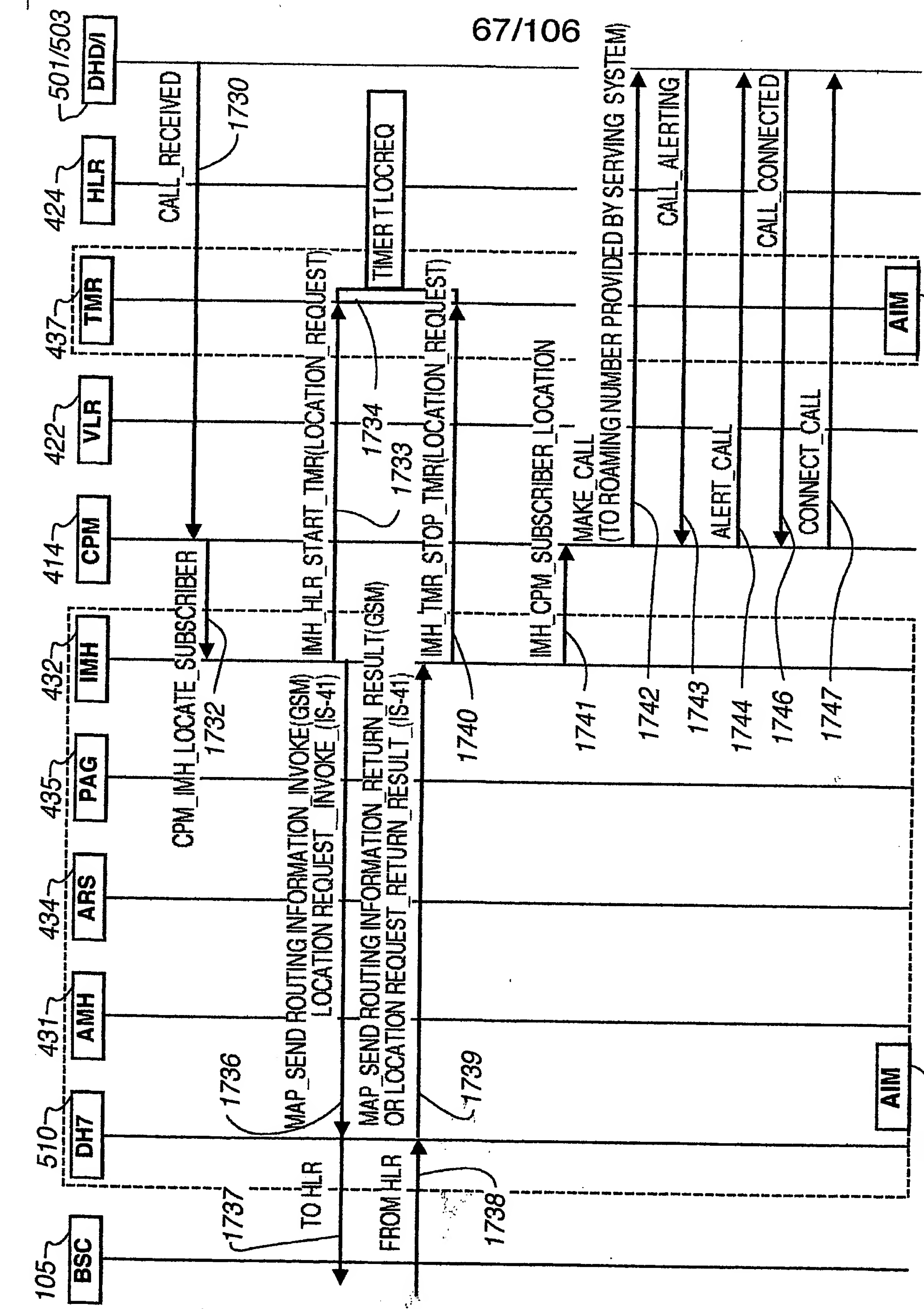

501/503
DHD/I
424
HLR
437
TMR
422
VLR
414
CPM
432
IMH
435
PAG
434
ARS
431
AMH
510
DH7
105
BSC
CALL_RECEIVED
1730
CPM_IMH_LOCATE_SUBSCRIBER
1732
TIMER T LOCREQ
IMH_HLR_START_TMR(LOCATION_REQUEST)
1734
1733
IMH_TMR_STOP_TMR(LOCATION_REQUEST)
MAP_SEND ROUTING INFORMATION_INVOKE(GSM)
LOCATION REQUEST_INVOKE_(IS-41)
1736
MAP_SEND ROUTING INFORMATION_RETURN_RESULT(GSM)
OR LOCATION REQUEST_RETURN_RESULT_(IS-41)
1739
1740
TO HLR
1737
FROM HLR
1738
IMH_CPM_SUBSCRIBER_LOCATION
1741
MAKE_CALL
(TO ROAMING NUMBER PROVIDED BY SERVING SYSTEM)
1742
CALL_ALERTING
1743
ALERT_CALL
1744
CALL_CONNECTED
1746
CONNECT_CALL
1747
AIM
430
AIM
430

Fig. 70

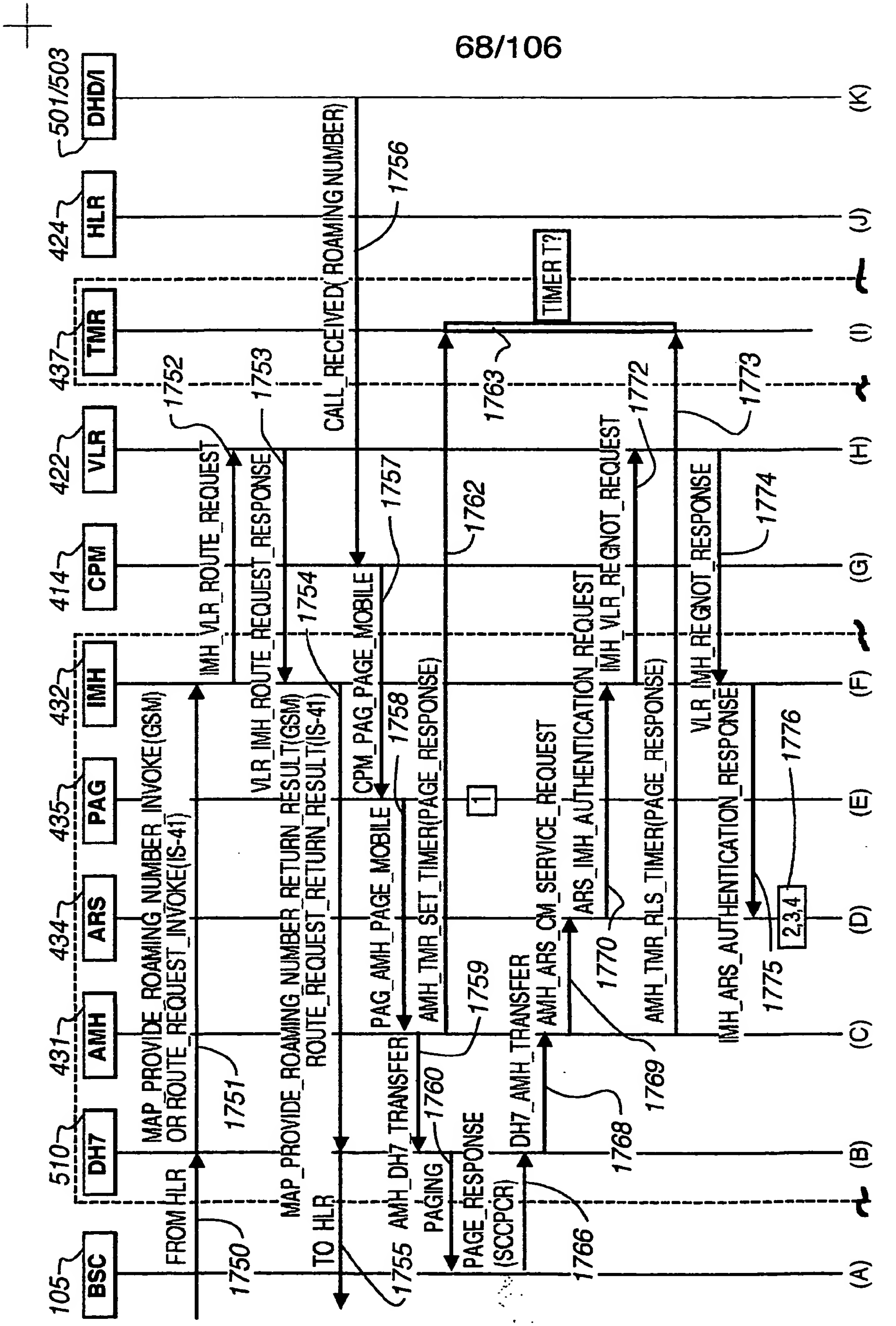

105
BSC
510
DH7
431
AMH
434
ARS
435
PAG
432
IMH
414
CPM
422
VLR
437
TMR
424
HLR
501/503
DHD/I
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
FROM HLR
1750
MAP_PROVIDE_ROAMING_NUMBER_INVOKE(GSM)
OR ROUTE_REQUEST_INVOKE(IS-41)
1751
IMH_VLR_ROUTE_REQUEST
1752
VLR_IMH_ROUTE_REQUEST_RESPONSE
1753
MAP_PROVIDE_ROAMING_NUMBER_RETURN_RESULT(GSM)
ROUTE_REQUEST_RETURN_RESULT(IS-41)
1754
TO HLR
1755
CALL_RECEIVED(ROAMING NUMBER)
1756
CPM_PAG_PAGE_MOBILE
1757
PAG_AMH_PAGE_MOBILE
1758
AMH_DH7_TRANSFER
PAGING
1760
AMH_TMR_SET_TIMER(PAGE_RESPONSE)
1759
1762
TIMER T?
1763
1
PAGE_RESPONSE
(SCCPCR)
1766
DH7_AMH_TRANSFER
1768
AMH_ARS_CM_SERVICE_REQUEST
1769
ARS_IMH_AUTHENTICATION_REQUEST
1770
IMH_VLR_REGNOT_REQUEST
1772
AMH_TMR_RLS_TIMER(PAGE_RESPONSE)
1773
VLR_IMH_REGNOT_RESPONSE
1774
IMH_ARS_AUTHENTICATION_RESPONSE
1775
2,3,4
1776

Fig. 71A

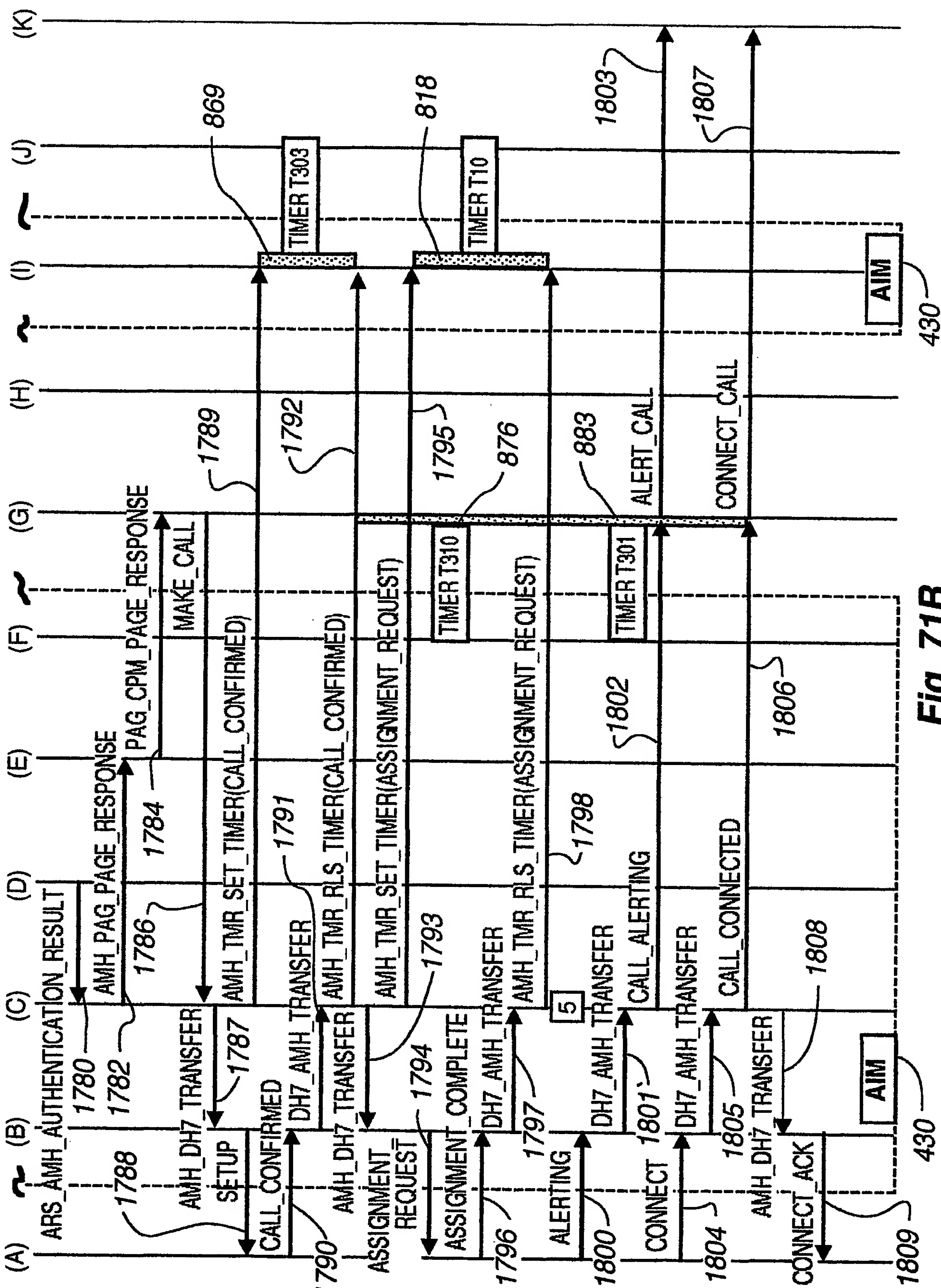
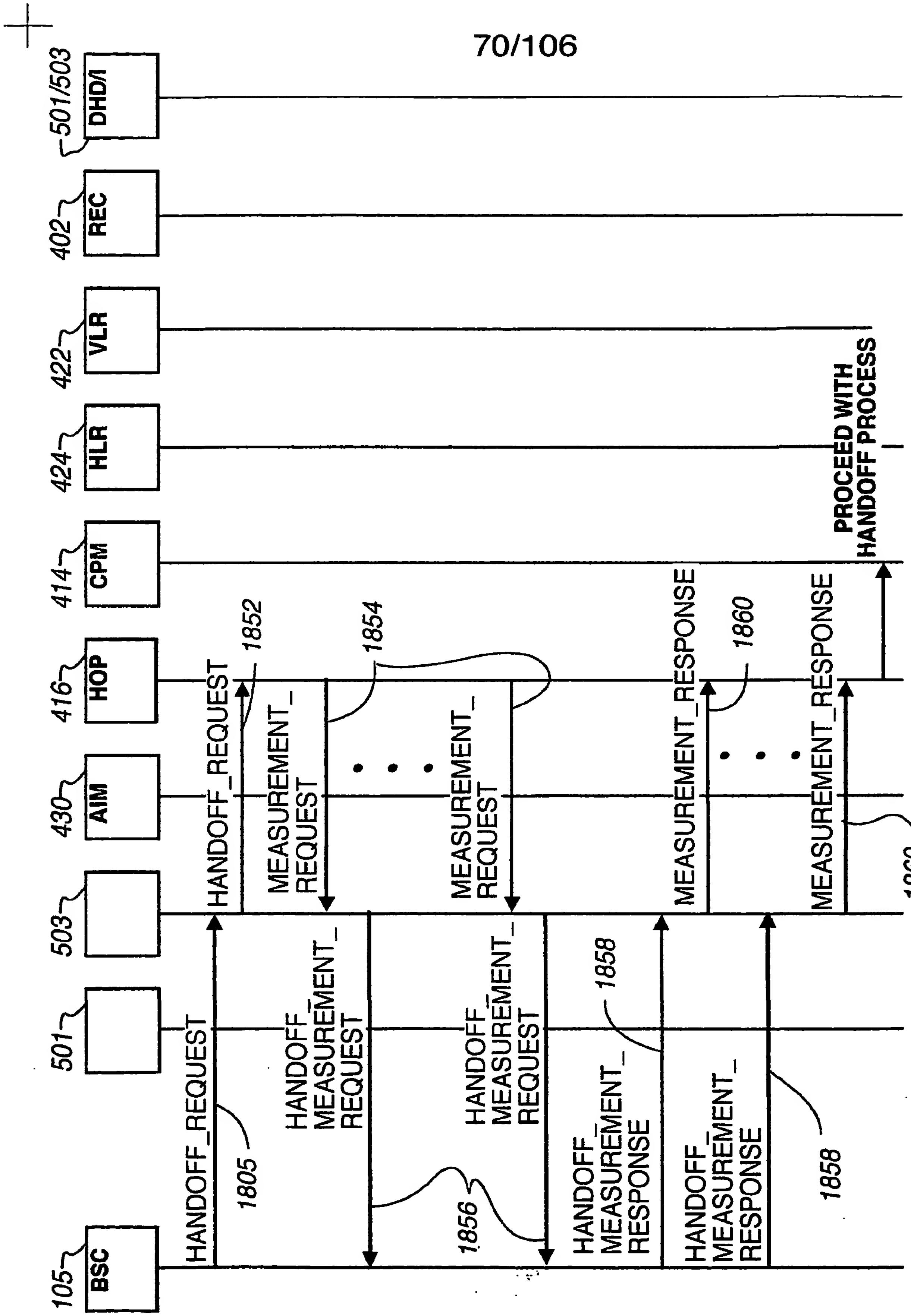

(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
(I)
(J)
(K)
ARS_AMH_AUTHENTICATION_RESULT
1780
AMH_PAG_PAGE_RESPONSE
1782
PAG_CPM_PAGE_RESPONSE
1784
MAKE_CALL
1786
AMH_DH7_TRANSFER
1787
SETUP
1788
AMH_TMR_SET_TIMER(CALL_CONFIRMED)
1789
869
TIMER T303
CALL_CONFIRMED
1790
DH7_AMH_TRANSFER
1791
AMH_TMR_RLS_TIMER(CALL_CONFIRMED)
1792
AMH_DH7_TRANSFER
1793
ASSIGNMENT_REQUEST
1794
AMH_TMR_SET_TIMER(ASSIGNMENT_REQUEST)
1795
818
TIMER T10
TIMER T310
876
ASSIGNMENT_COMPLETE
1796
DH7_AMH_TRANSFER
1797
AMH_TMR_RLS_TIMER(ASSIGNMENT_REQUEST)
1798
5
ALERTING
1800
DH7_AMH_TRANSFER
1801
CALL_ALERTING
1802
TIMER T301
883
ALERT_CALL
1803
CONNECT
1804
DH7_AMH_TRANSFER
1805
CALL_CONNECTED
1806
CONNECT_CALL
1807
AMH_DH7_TRANSFER
1808
CONNECT_ACK
1809
AIM
430
AIM
430

Fig. 71B



105
BSC
501
503
430
AIM
416
HOP
414
CPM
424
HLR
422
VLR
402
REC
501/503
DHD/I
HANDOFF_REQUEST
1805
HANDOFF_REQUEST
1852
HANDOFF_
MEASUREMENT_
REQUEST
MEASUREMENT_
REQUEST
1854
1856
HANDOFF_
MEASUREMENT_
RESPONSE
1858
MEASUREMENT_RESPONSE
1860
PROCEED WITH
HANDOFF PROCESS

Fig. 72

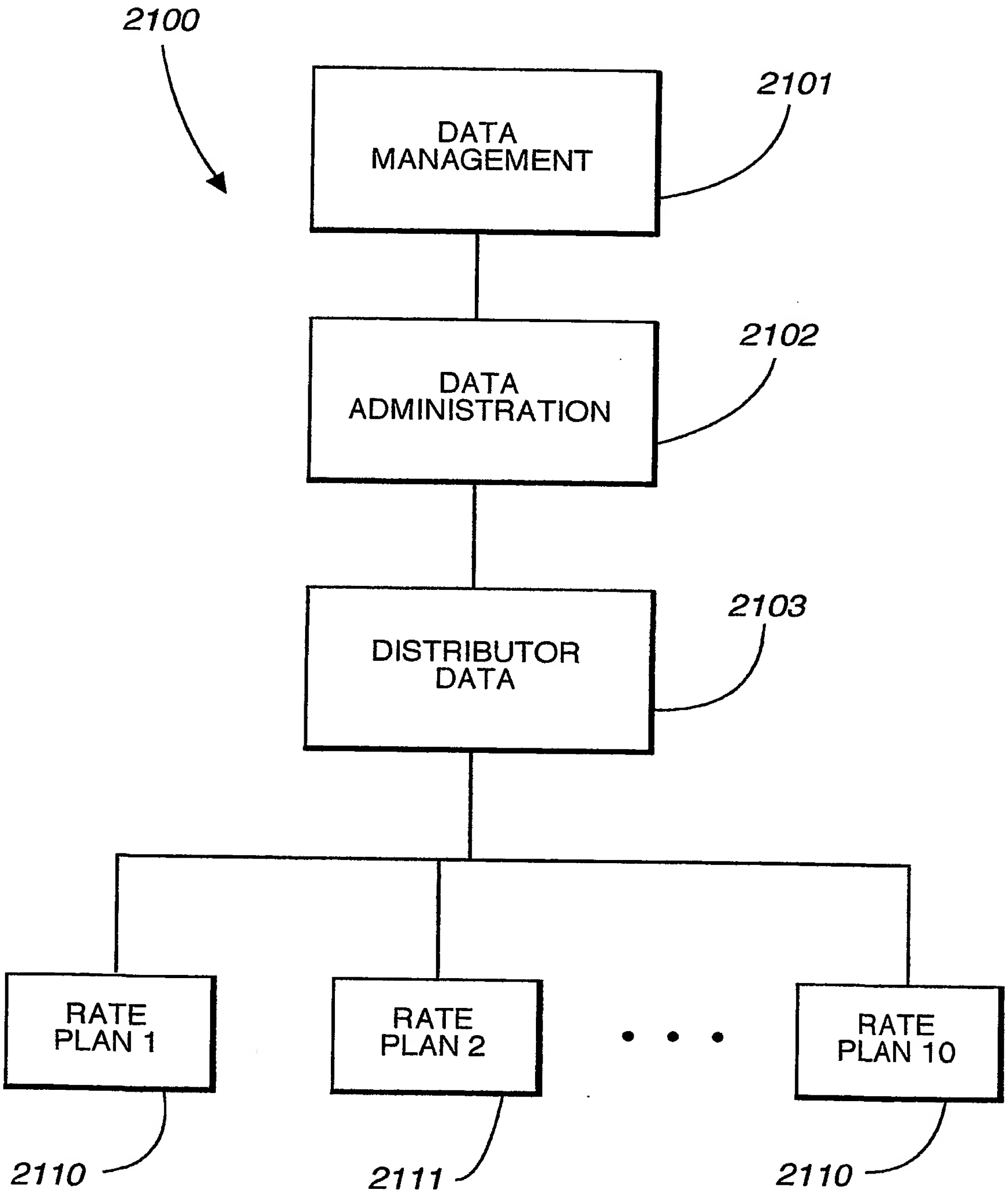

2100
DATA MANAGEMENT
2101
DATA ADMINISTRATION
2102
DISTRIBUTOR DATA
2103
RATE PLAN 1
RATE PLAN 2
RATE PLAN 10
2110
2111
2110

Fig. 73

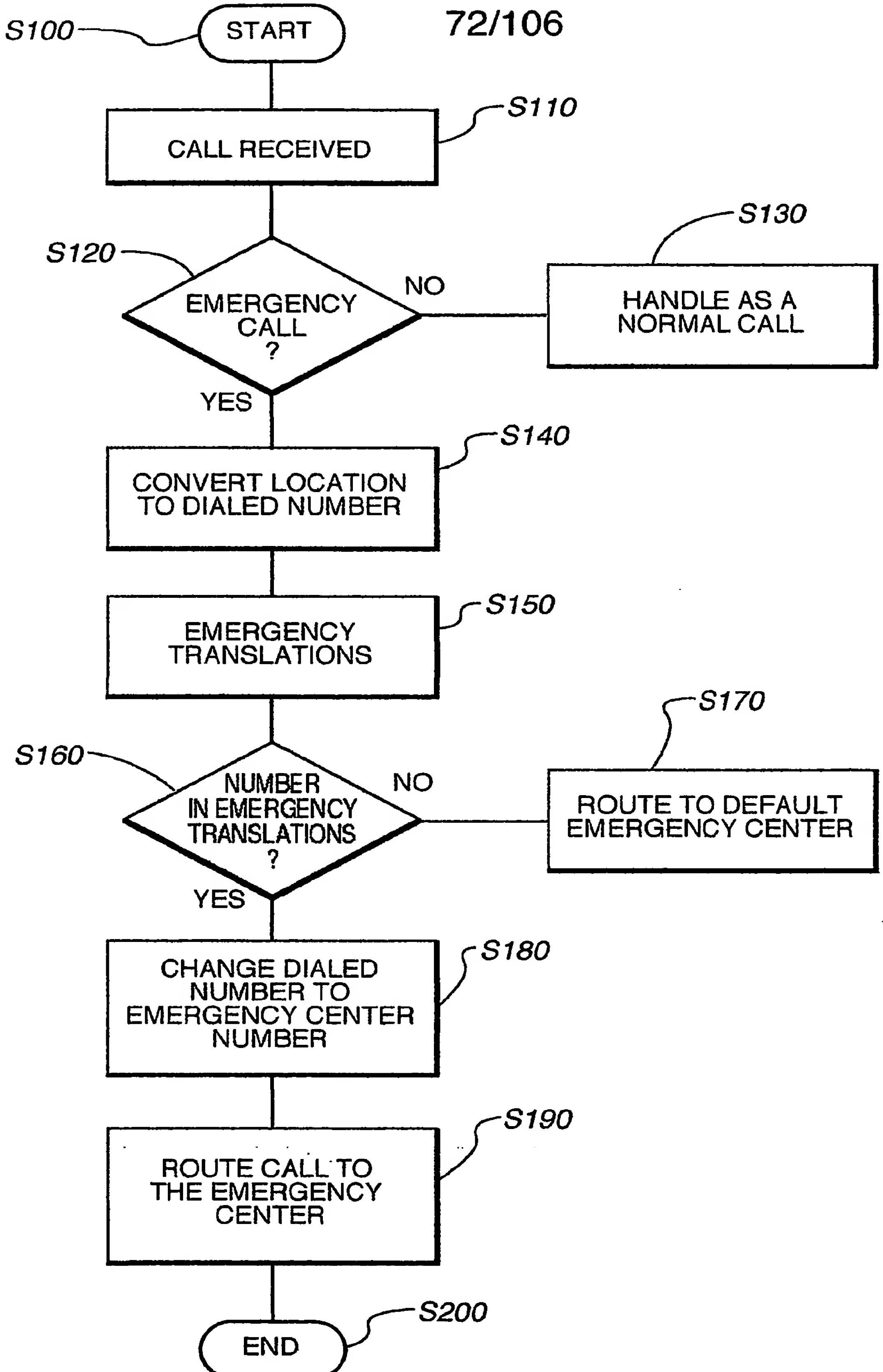

S100
START
S110
CALL RECEIVED
S120
EMERGENCY CALL ?
NO
S130
HANDLE AS A NORMAL CALL
YES
S140
CONVERT LOCATION TO DIALED NUMBER
S150
EMERGENCY TRANSLATIONS
S160
NUMBER IN EMERGENCY TRANSLATIONS ?
NO
S170
ROUTE TO DEFAULT EMERGENCY CENTER
YES
S180
CHANGE DIALED NUMBER TO EMERGENCY CENTER NUMBER
S190
ROUTE CALL TO THE EMERGENCY CENTER
S200
END

Fig. 74

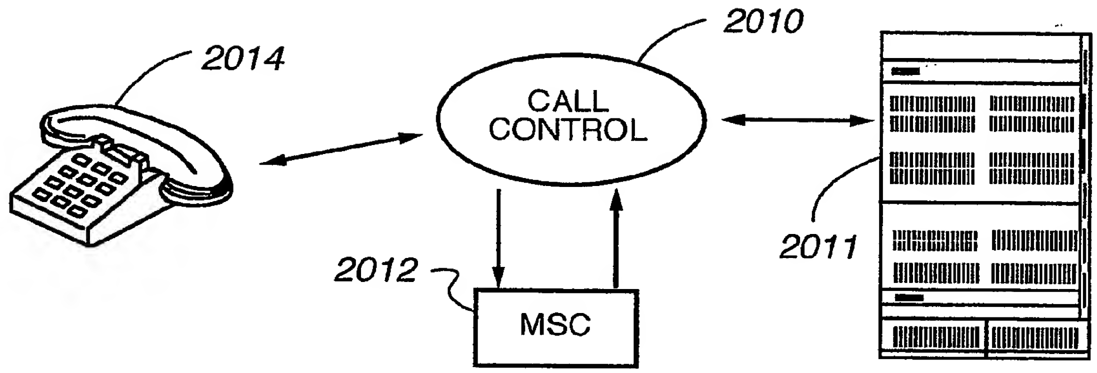


Fig. 75

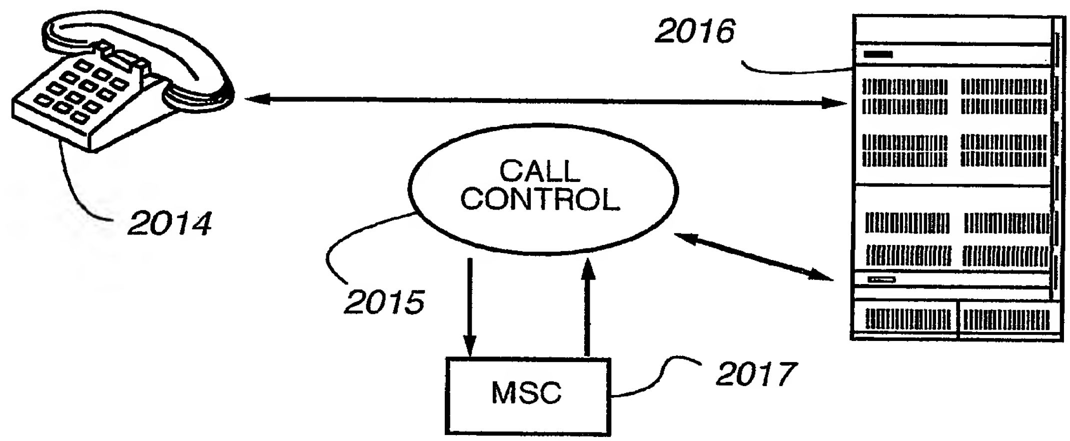


Fig. 76

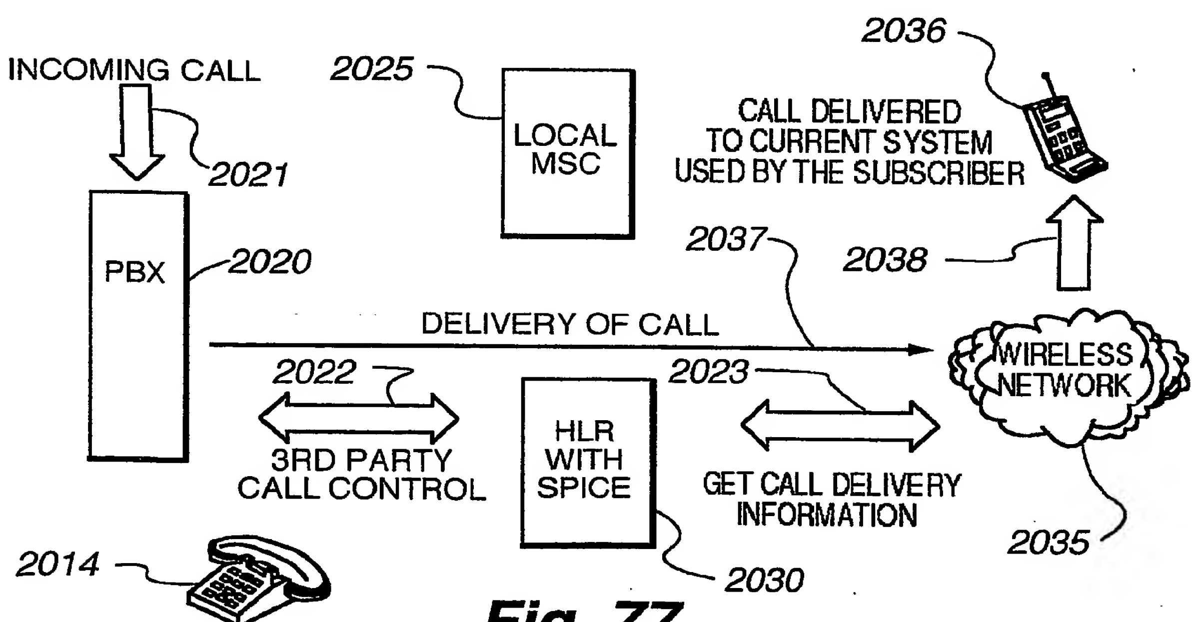


Fig. 77

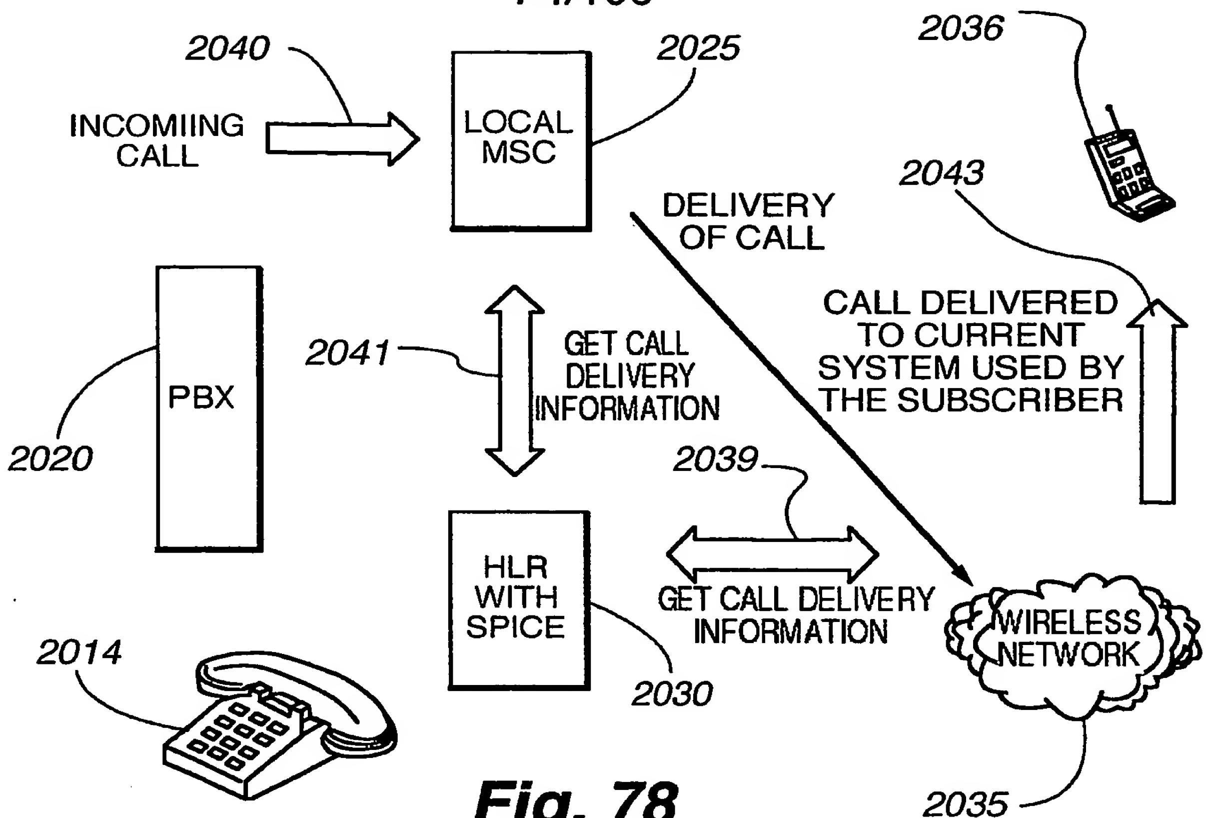

2040
INCOMIING CALL
LOCAL MSC
2025
2036
2043
DELIVERY OF CALL
CALL DELIVERED TO CURRENT SYSTEM USED BY THE SUBSCRIBER
PBX
2041
GET CALL DELIVERY INFORMATION
2020
2039
HLR WITH SPICE
GET CALL DELIVERY INFORMATION
WIRELESS NETWORK
2014
2030
2035

Fig. 78

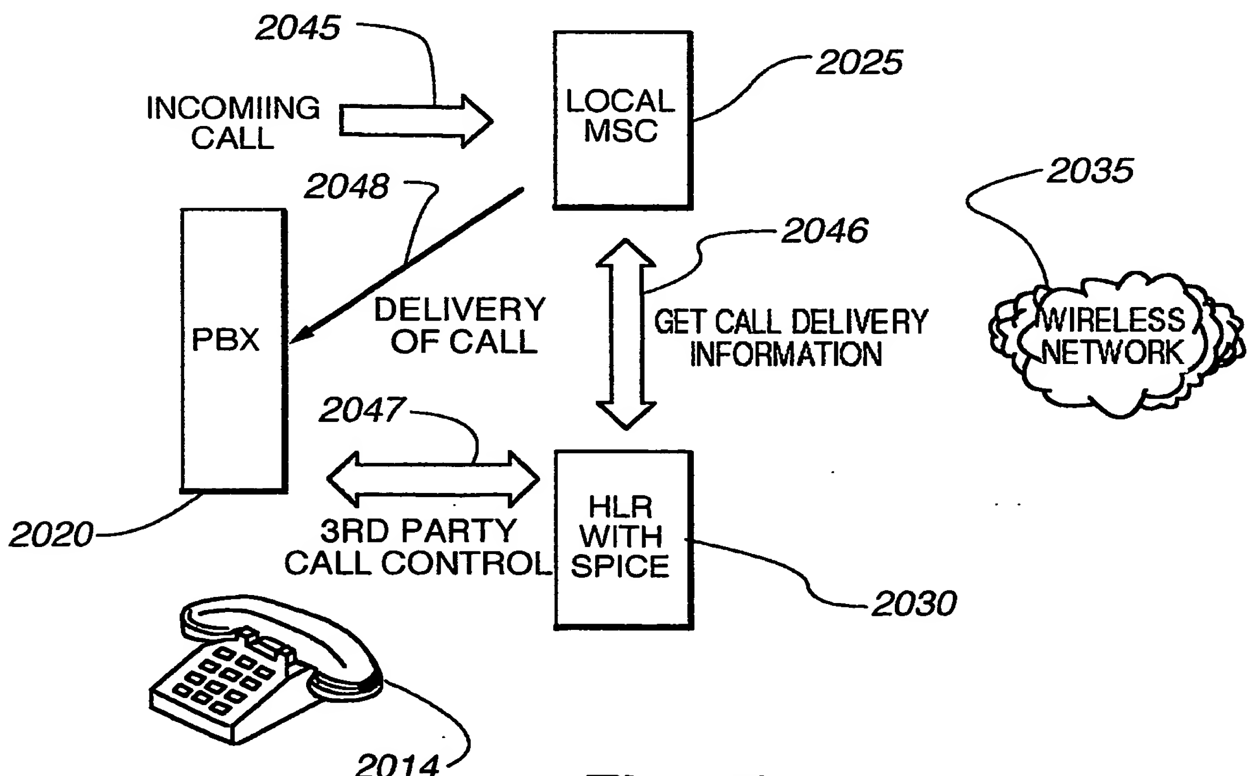

2045
INCOMIING CALL
LOCAL MSC
2025
2048
2035
2046
PBX
DELIVERY OF CALL
GET CALL DELIVERY INFORMATION
WIRELESS NETWORK
2047
2020
3RD PARTY CALL CONTROL
HLR WITH SPICE
2030
2014

Fig. 79

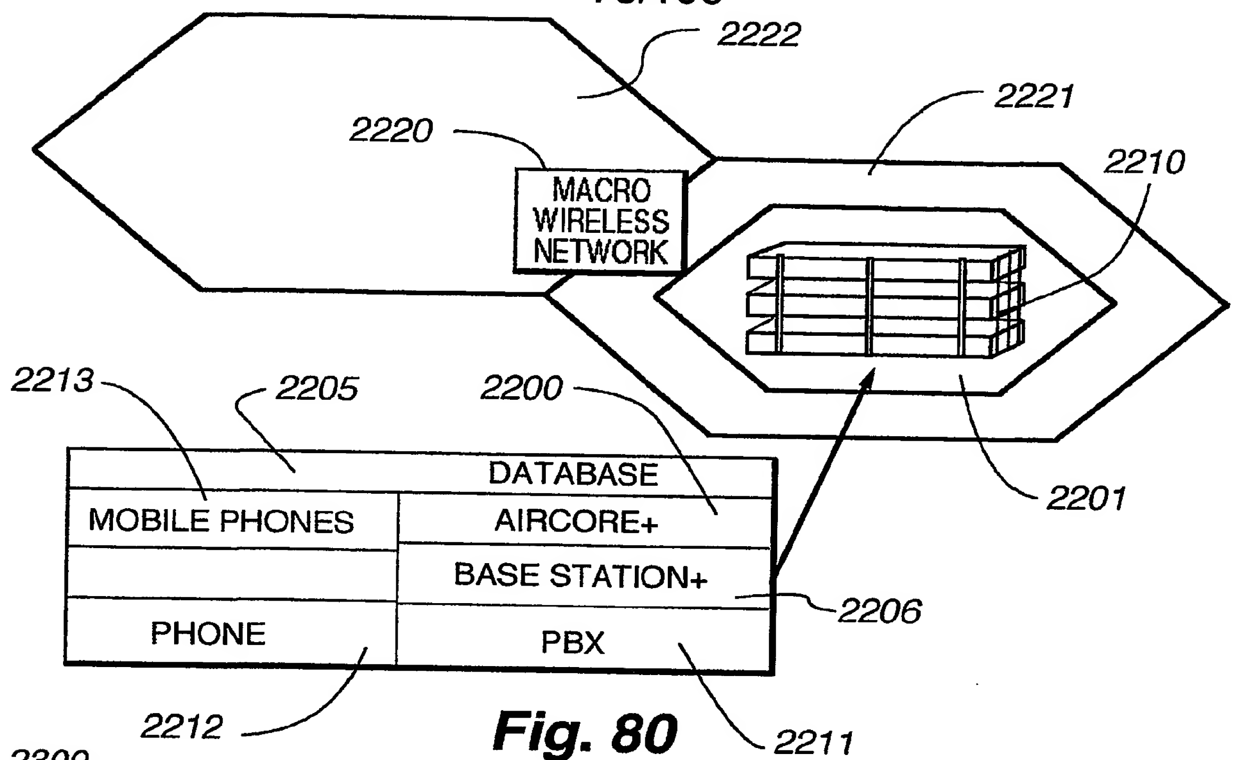

2222
2221
2220
MACRO WIRELESS NETWORK
2210
2213
2205
2200
DATABASE
MOBILE PHONES
AIRCORE+
BASE STATION+
2206
PHONE
PBX
2201
2212
2211

Fig. 80

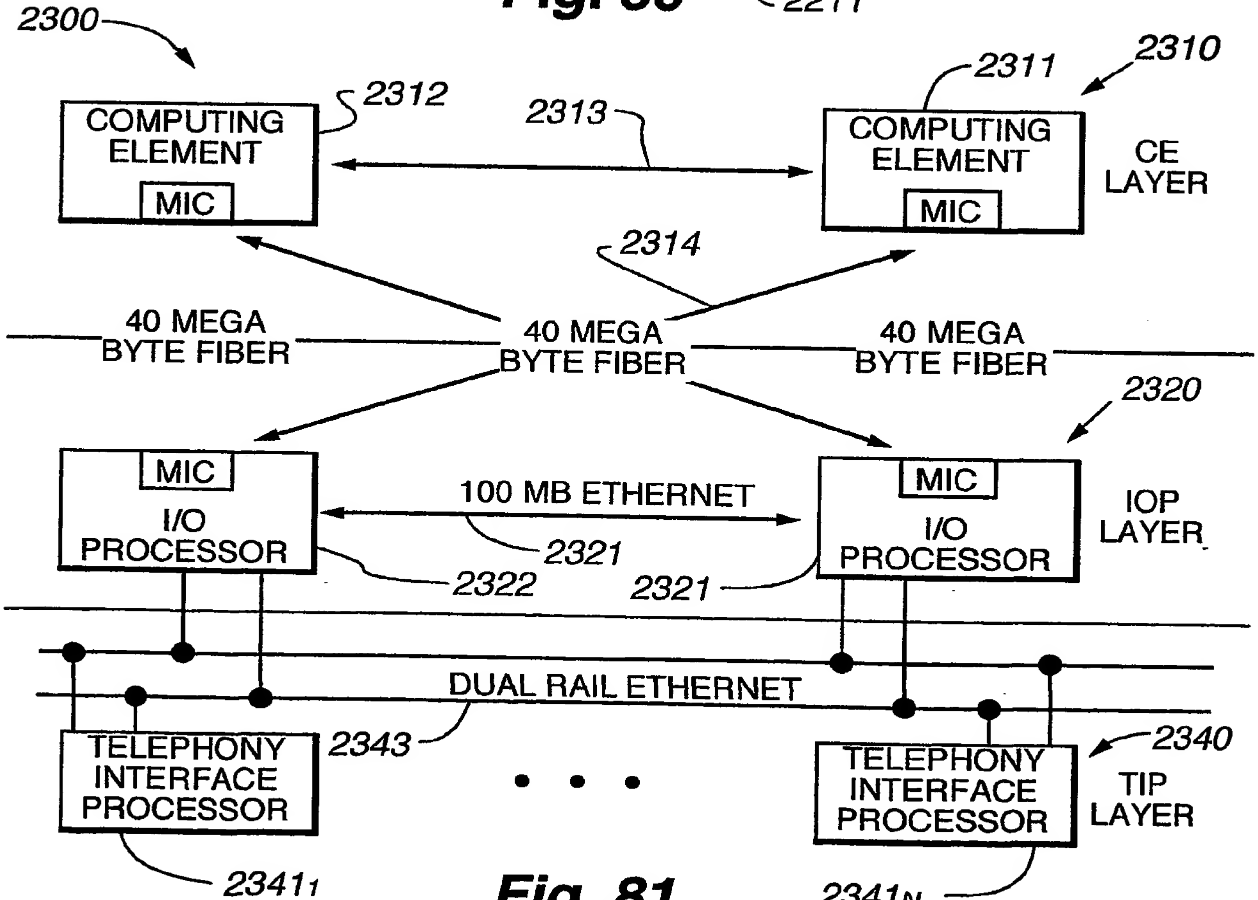

2300
2312
2313
2311
2310
COMPUTING ELEMENT
MIC
COMPUTING ELEMENT
MIC
CE LAYER
2314
40 MEGA BYTE FIBER
40 MEGA BYTE FIBER
40 MEGA BYTE FIBER
2320
MIC
I/O PROCESSOR
100 MB ETHERNET
MIC
I/O PROCESSOR
IOP LAYER
2321
2322
2321
DUAL RAIL ETHERNET
2343
TELEPHONY INTERFACE PROCESSOR
TELEPHONY INTERFACE PROCESSOR
2340
TIP LAYER
2341₁
2341N

Fig. 81

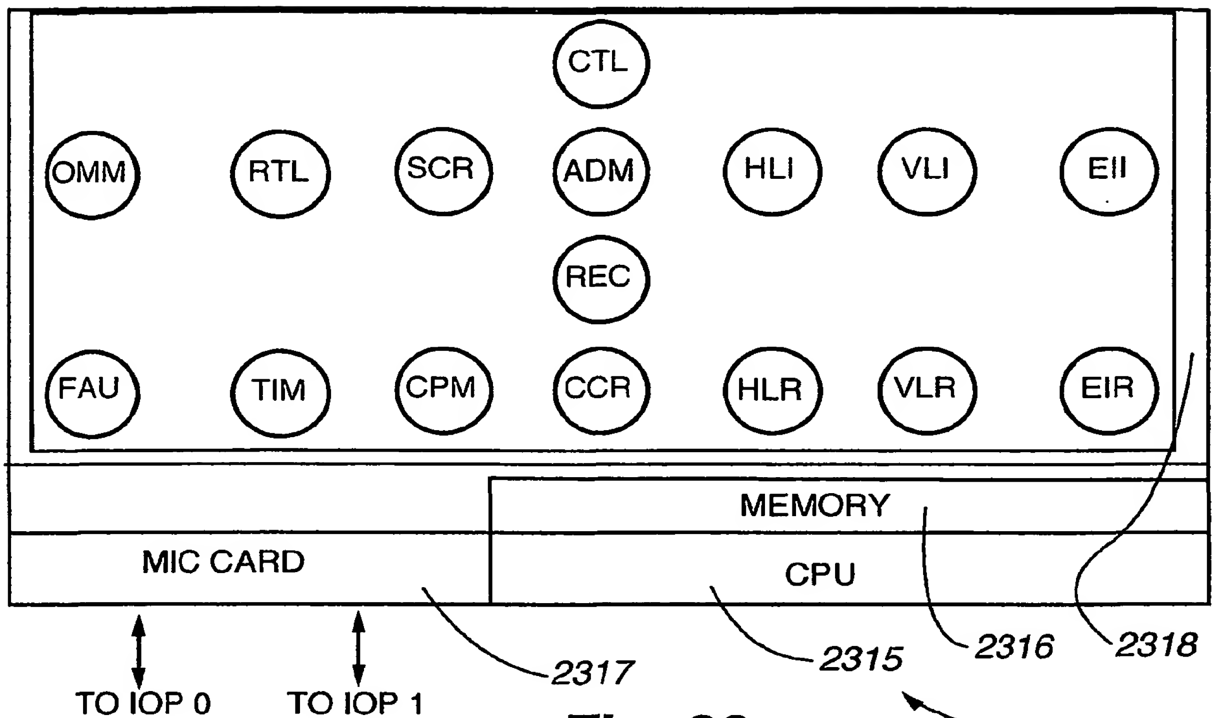

CTL
OMM
RTL
SCR
ADM
HLI
VLI
EII
REC
FAU
TIM
CPM
CCR
HLR
VLR
EIR
MEMORY
MIC CARD
CPU
TO IOP 0
TO IOP 1
2317
2315
2316
2318
2310

Fig. 82

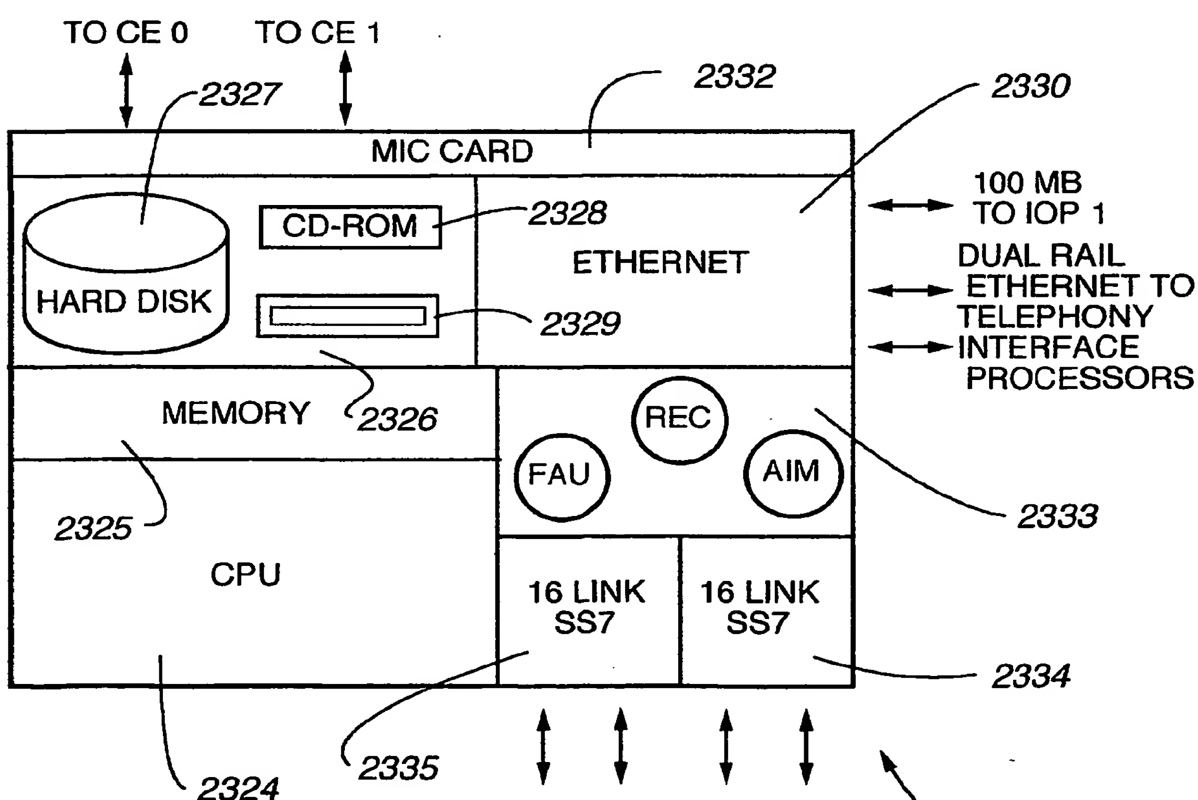

TO CE 0
TO CE 1
2327
2332
2330
MIC CARD
CD-ROM
2328
100 MB
TO IOP 1
ETHERNET
HARD DISK
DUAL RAIL
ETHERNET TO
TELEPHONY
INTERFACE
PROCESSORS
2329
MEMORY
2326
REC
FAU
AIM
2333
2325
CPU
16 LINK
SS7
16 LINK
SS7
2334
2324
2335
2320

Fig. 83

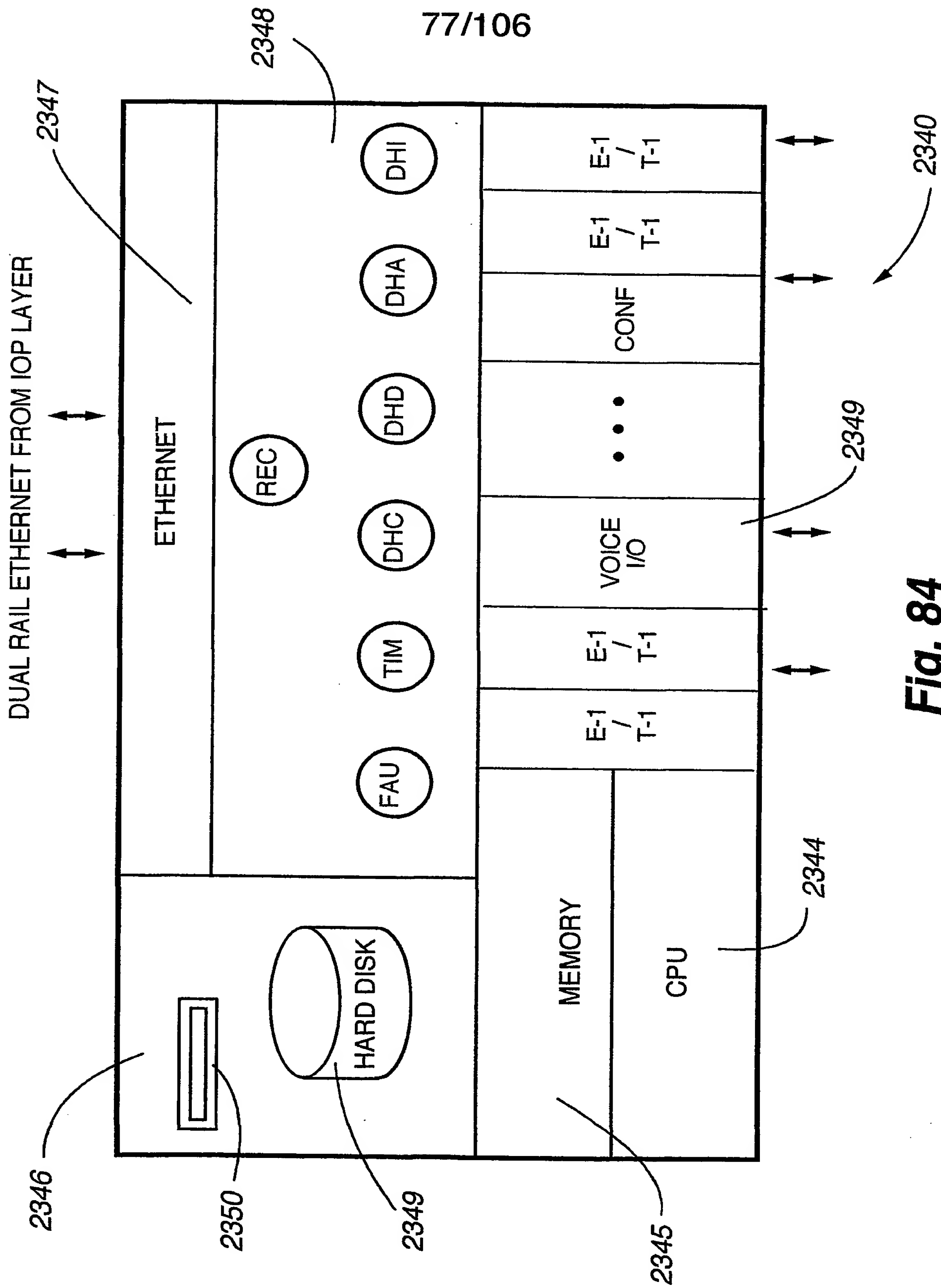

DUAL RAIL ETHERNET FROM IOP LAYER
ETHERNET
2347
2348
FAU
TIM
DHC
REC
DHD
DHA
DHI
E-1 / T-1
E-1 / T-1
VOICE I/O
CONF
E-1 / T-1
E-1 / T-1
2349
2340
HARD DISK
MEMORY
CPU
2344
2346
2350
2349
2345

Fig. 84

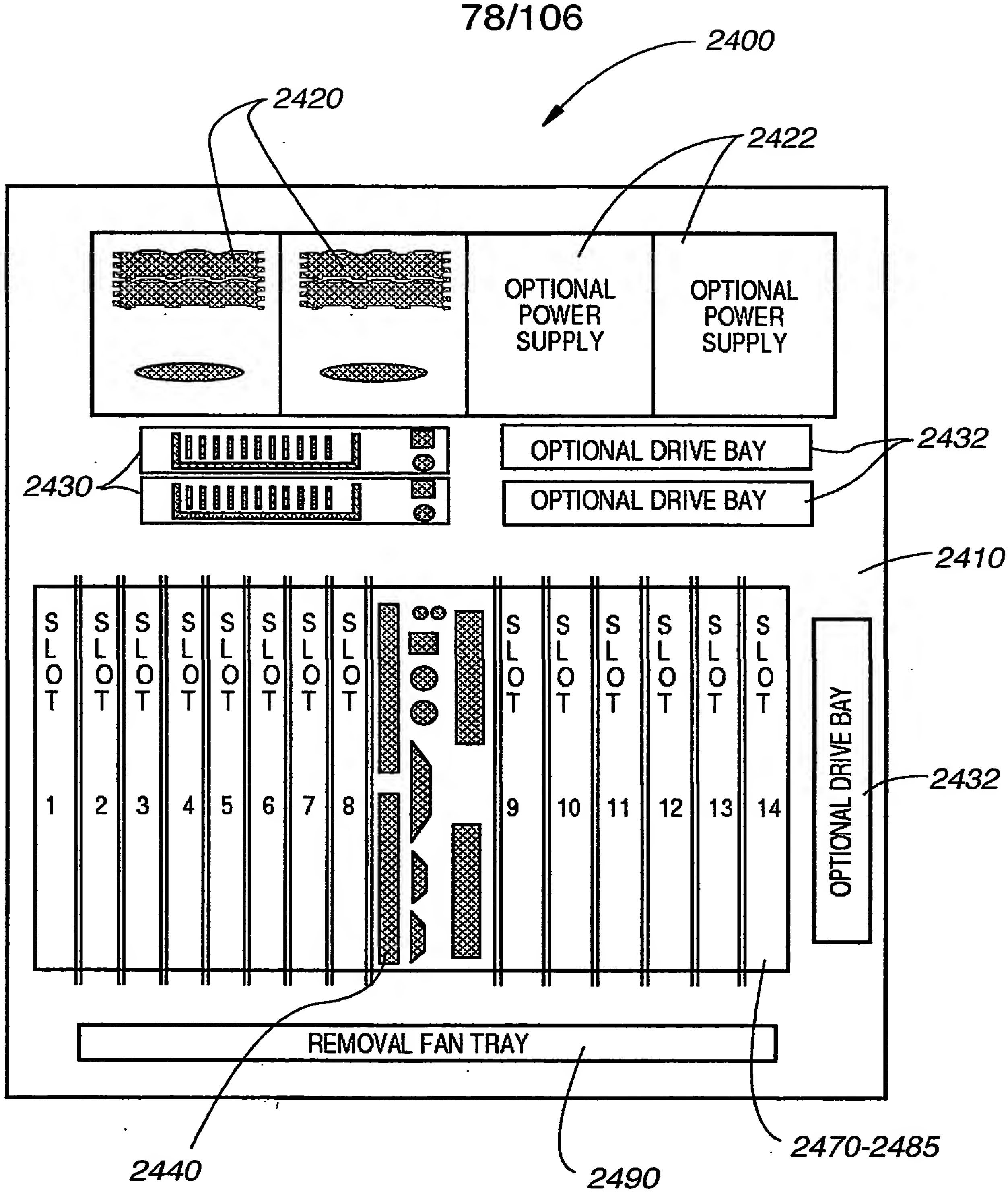

2400
2420
2422
OPTIONAL POWER SUPPLY
OPTIONAL POWER SUPPLY
2430
OPTIONAL DRIVE BAY
OPTIONAL DRIVE BAY
2432
2410
SLOT 1
SLOT 2
SLOT 3
SLOT 4
SLOT 5
SLOT 6
SLOT 7
SLOT 8
SLOT 9
SLOT 10
SLOT 11
SLOT 12
SLOT 13
SLOT 14
OPTIONAL DRIVE BAY
2432
REMOVAL FAN TRAY
2440
2490
2470-2485

Fig. 85

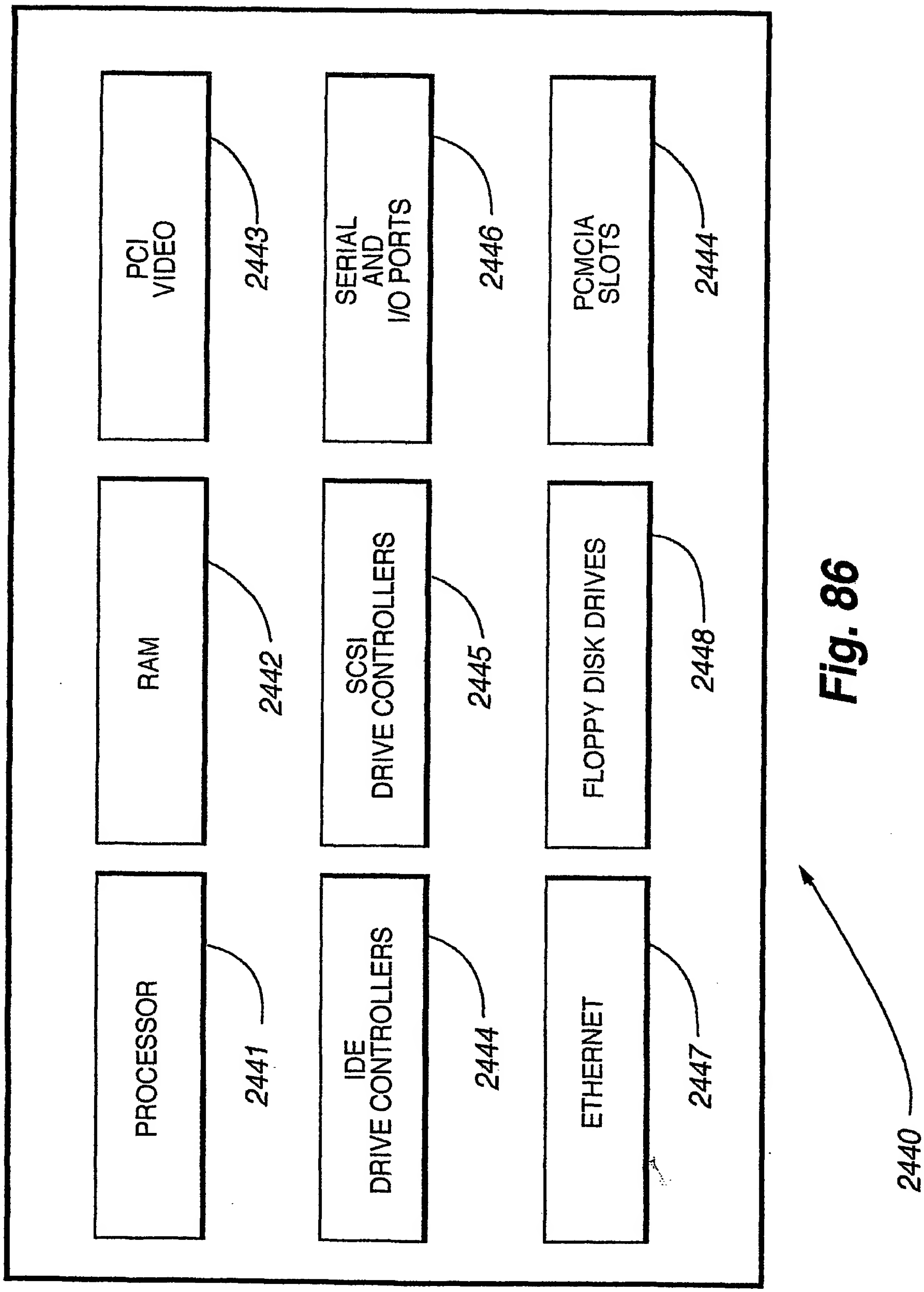

PCI VIDEO
2443
SERIAL AND I/O PORTS
2446
PCMCIA SLOTS
2444
RAM
2442
SCSI DRIVE CONTROLLERS
2445
FLOPPY DISK DRIVES
2448
PROCESSOR
2441
IDE DRIVE CONTROLLERS
2444
ETHERNET
2447
2440

Fig. 86

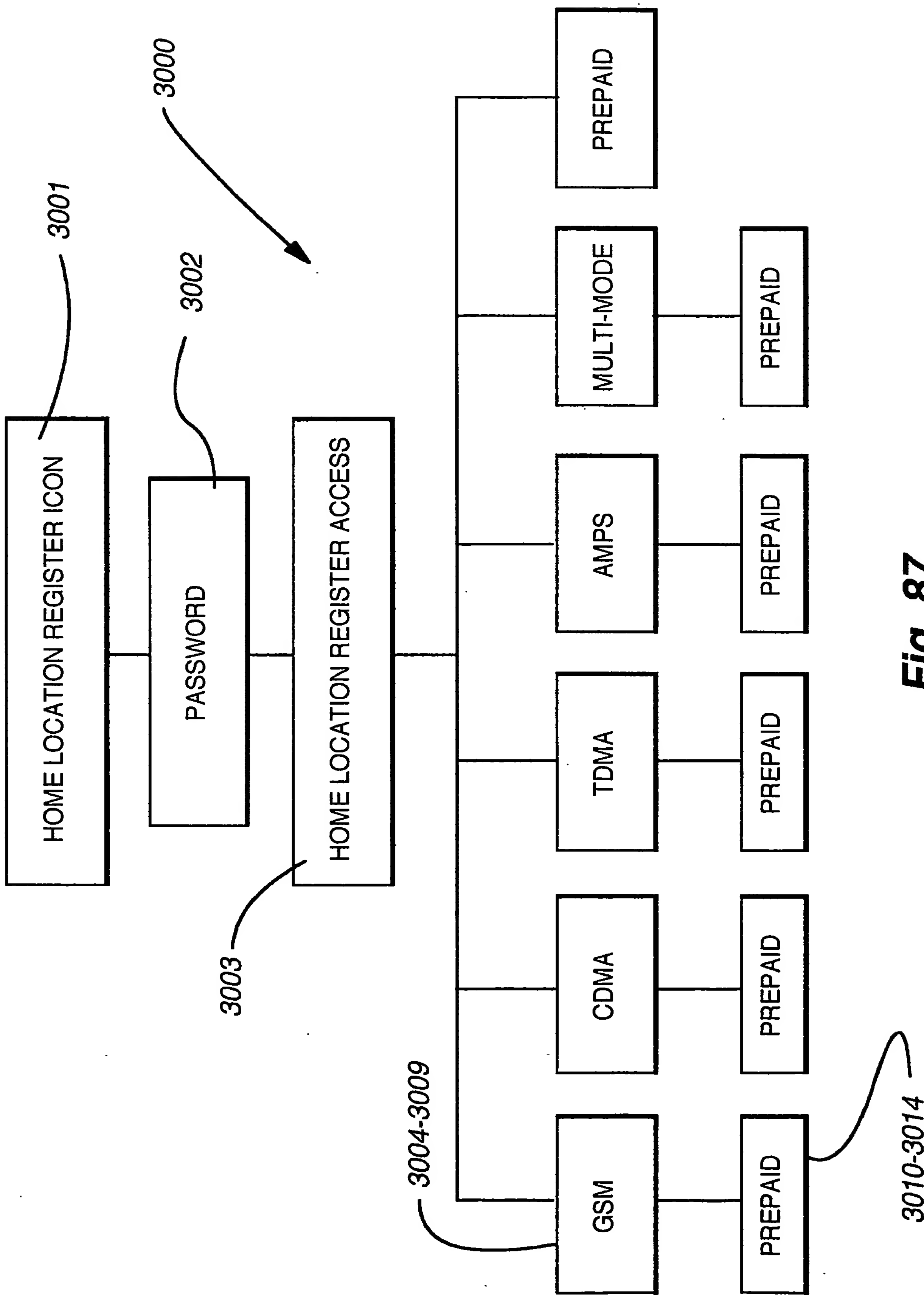

3000
3001
HOME LOCATION REGISTER ICON
3002
PASSWORD
HOME LOCATION REGISTER ACCESS
3003
GSM
CDMA
TDMA
AMPS
MULTI-MODE
PREPAID
PREPAID
PREPAID
PREPAID
PREPAID
PREPAID
PREPAID
3004-3009
3010-3014

Fig. 87

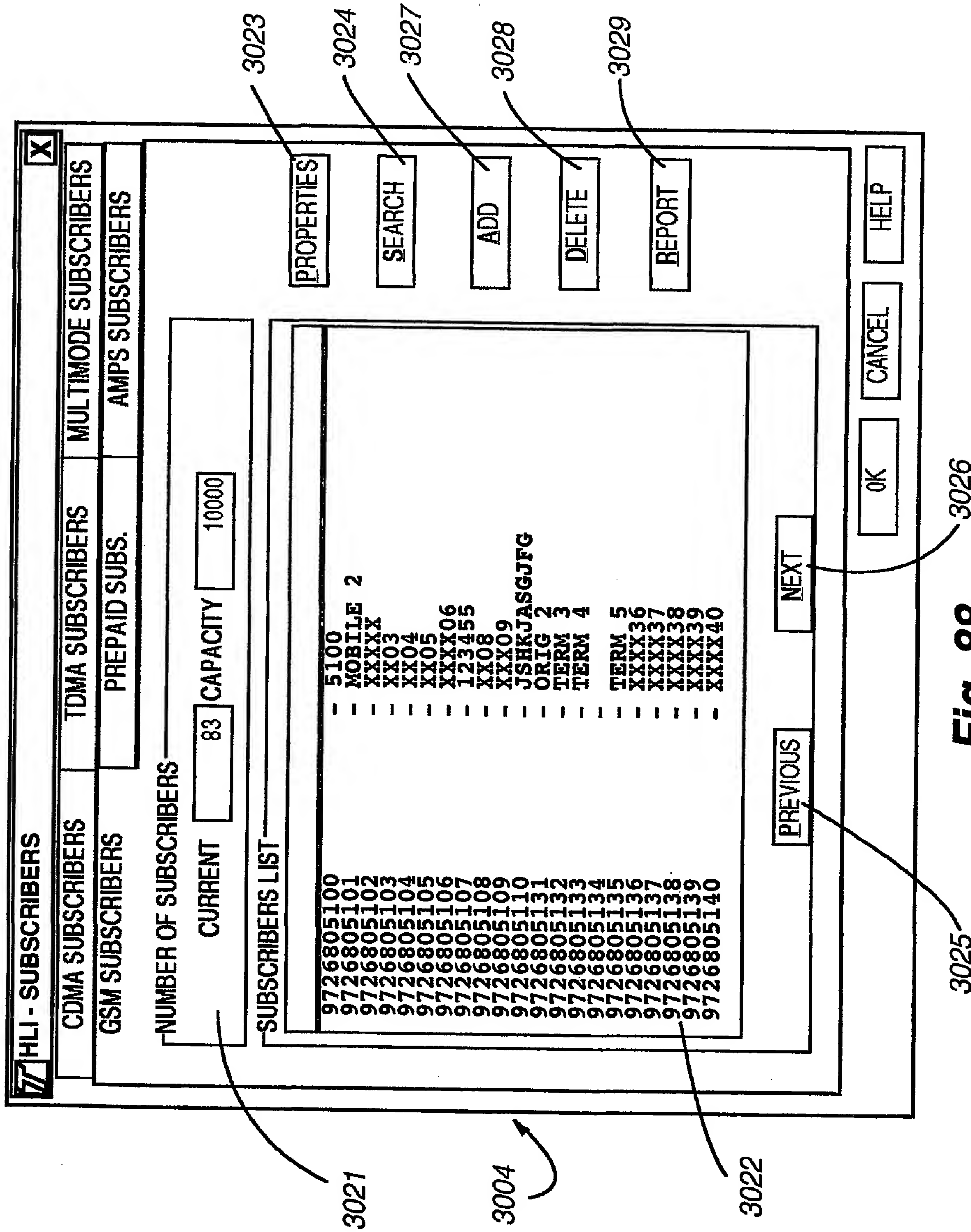
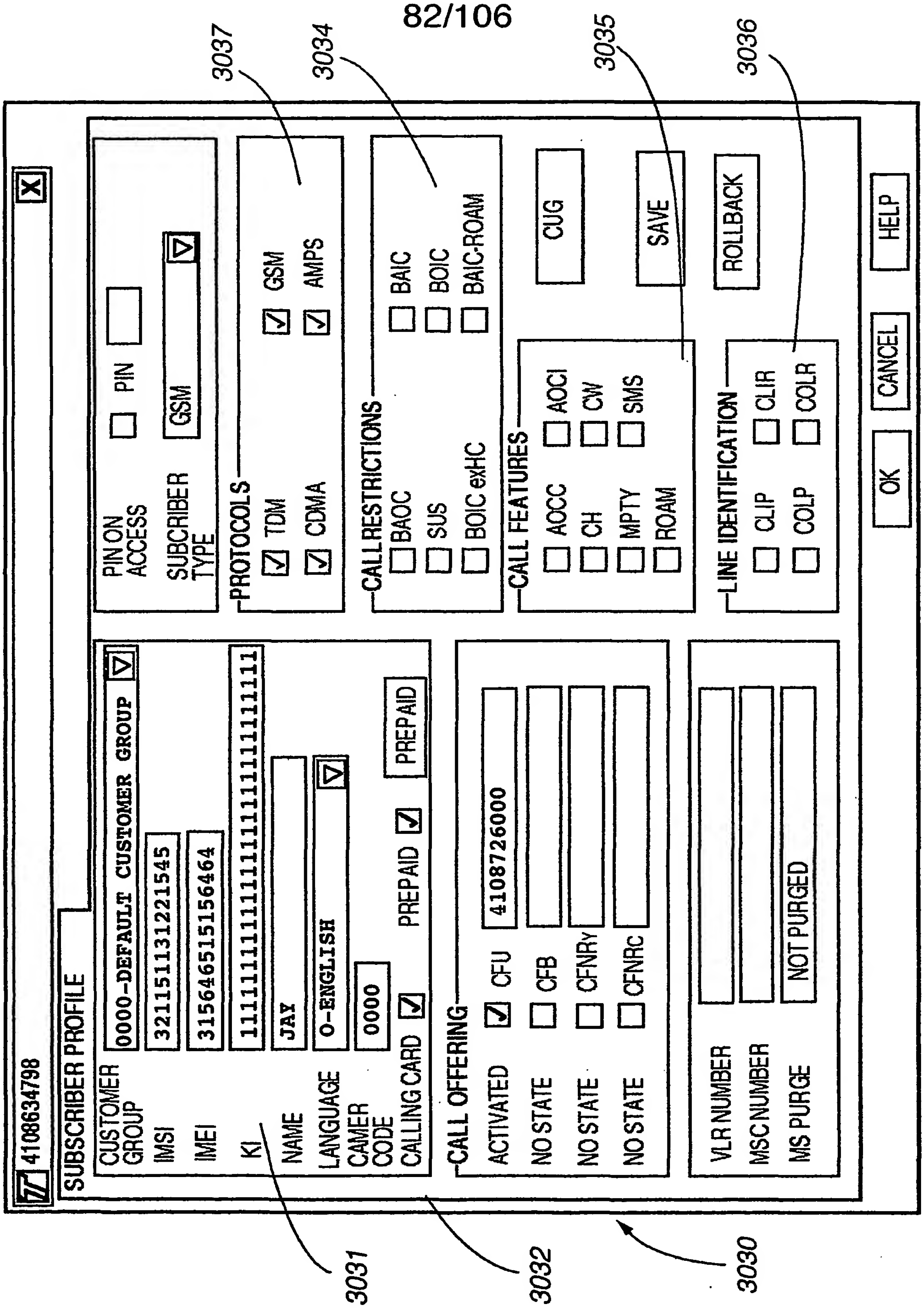

HLI - SUBSCRIBERS
X
CDMA SUBSCRIBERS
TDMA SUBSCRIBERS
MULTIMODE SUBSCRIBERS
GSM SUBSCRIBERS
PREPAID SUBS.
AMPS SUBSCRIBERS
NUMBER OF SUBSCRIBERS
CURRENT
83
CAPACITY
10000
SUBSCRIBERS LIST
9726805100 - 5100
9726805101 - MOBILE 2
9726805102 - XXXXX
9726805103 - XX03
9726805104 - XX04
9726805105 - XX05
9726805106 - XXXX06
9726805107 - 123455
9726805108 - XX08
9726805109 - XXX09
9726805110 - JSHKJASGJFG
9726805131 - ORIG 2
9726805132 - TERM 3
9726805133 - TERM 4
9726805134 -
9726805135 - TERM 5
9726805136 - XXXX36
9726805137 - XXXX37
9726805138 - XXXX38
9726805139 - XXXX39
9726805140 - XXXX40
PREVIOUS
NEXT
PROPERTIES
SEARCH
ADD
DELETE
REPORT
OK
CANCEL
HELP
3021
3004
3022
3023
3024
3027
3028
3029
3025
3026

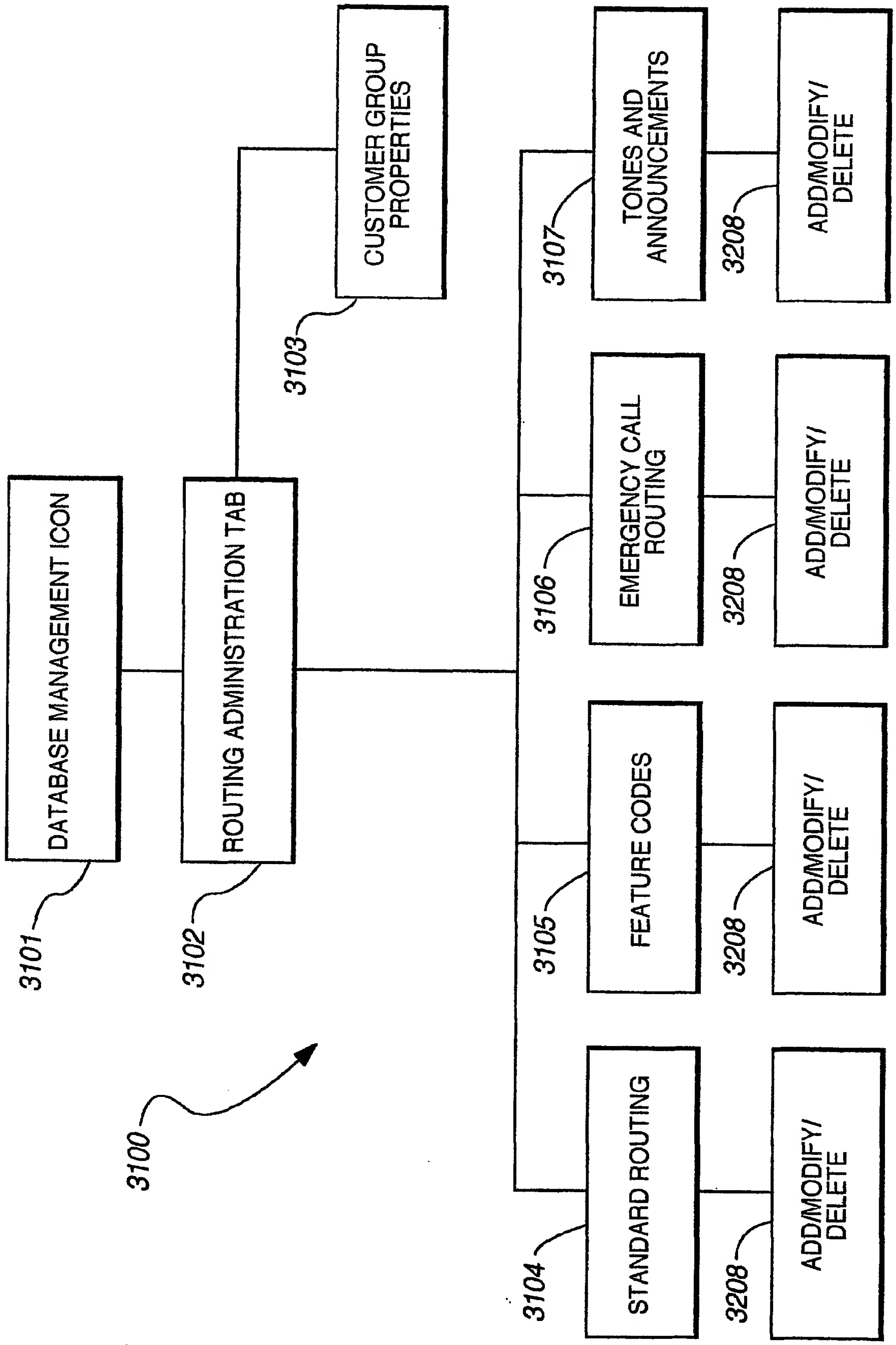
Fig. 88

82/106



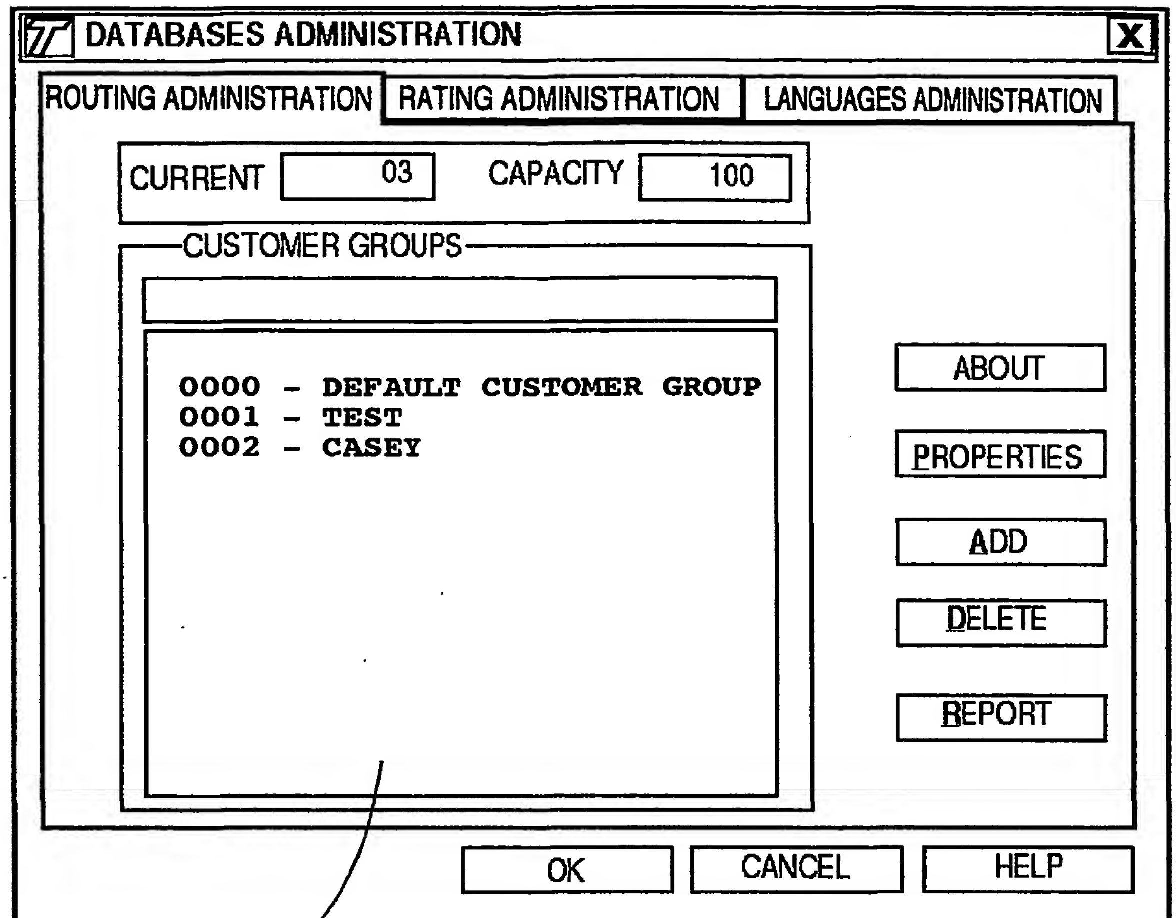
4108634798
SUBSCRIBER PROFILE
CUSTOMER GROUP
0000-DEFAULT CUSTOMER GROUP
IMSI
321151131221545
IMEI
315646515156464
KI
11111111111111111111111111111111
NAME
JAY
LANGUAGE
0-ENGLISH
CAMER CODE
0000
CALLING CARD
PREPAID
PREPAID
CALL OFFERING
ACTIVATED
CFU
4108726000
NO STATE
CFB
NO STATE
CFNRy
NO STATE
CFNRc
VLR NUMBER
MSC NUMBER
MS PURGE
NOT PURGED
PIN ON ACCESS
PIN
SUBCRIBER TYPE
GSM
PROTOCOLS
TDM
GSM
CDMA
AMPS
CALL RESTRICTIONS
BAOC
BAIC
SUS
BOIC
BOIC exHC
BAIC-ROAM
CALL FEATURES
AOCC
AOCI
CH
CW
MPTY
SMS
ROAM
CUG
SAVE
LINE IDENTIFICATION
CLIP
CLIR
COLP
COLR
ROLLBACK
OK
CANCEL
HELP
3037
3034
3035
3036
3031
3032
3030

Fig. 89



DATABASE MANAGEMENT ICON
ROUTING ADMINISTRATION TAB
CUSTOMER GROUP PROPERTIES
STANDARD ROUTING
FEATURE CODES
EMERGENCY CALL ROUTING
TONES AND ANNOUNCEMENTS
ADD/MODIFY/ DELETE
ADD/MODIFY/ DELETE
ADD/MODIFY/ DELETE
ADD/MODIFY/ DELETE
3100
3101
3102
3103
3104
3105
3106
3107
3208
3208
3208
3208

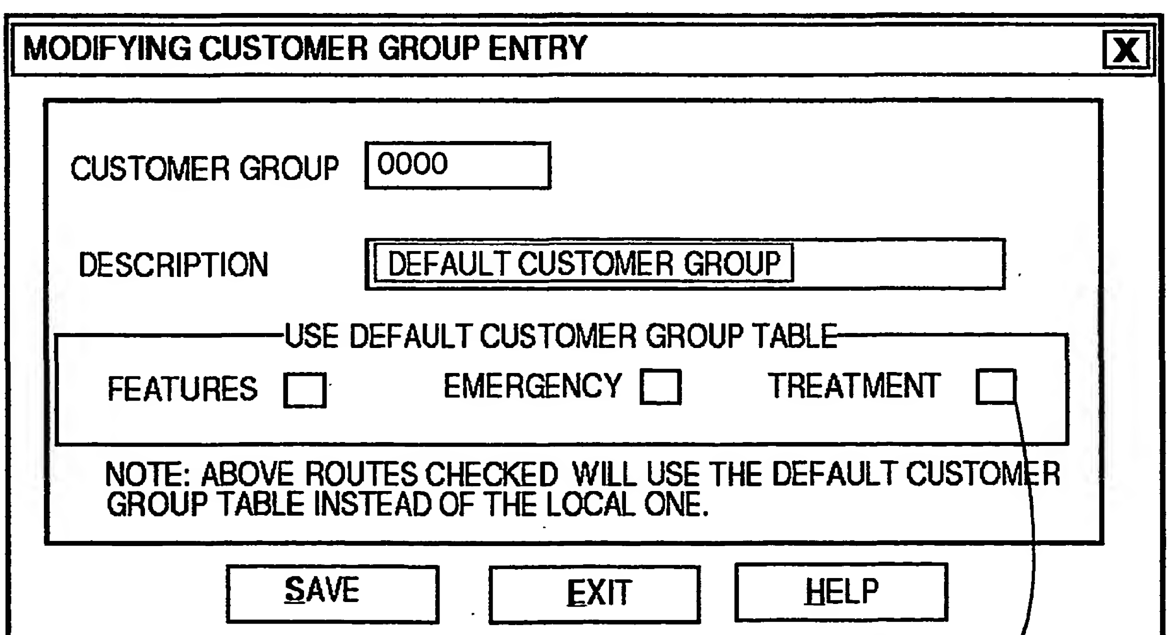
Fig. 90



3111

Fig. 91

3112



3120

Fig. 92

3121

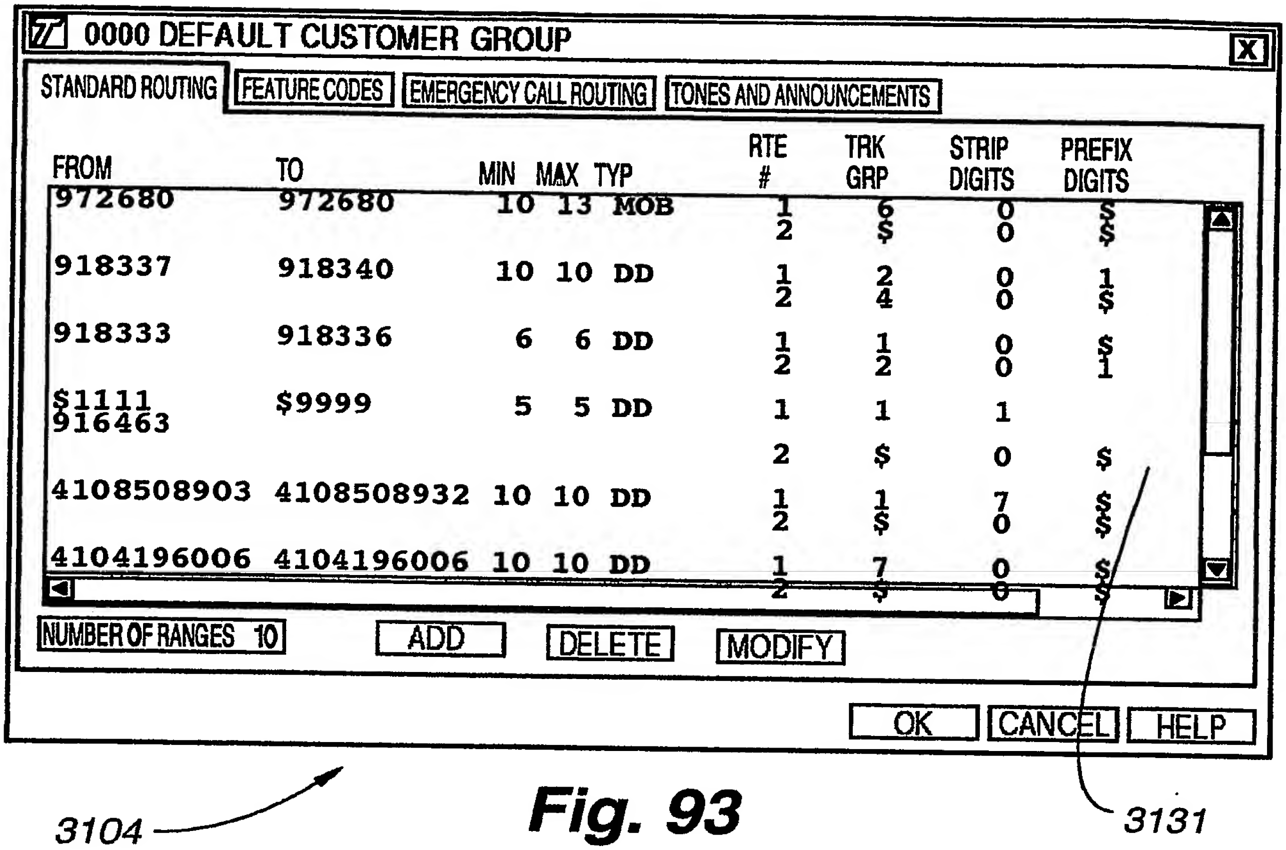

0000 DEFAULT CUSTOMER GROUP
STANDARD ROUTING
FEATURE CODES
EMERGENCY CALL ROUTING
TONES AND ANNOUNCEMENTS
FROM TO MIN MAX TYP RTE # TRK GRP STRIP DIGITS PREFIX DIGITS
972680 972680 10 13 MOB 1 2 6 $ 0 0 $ $
918337 918340 10 10 DD 1 2 2 4 0 0 1 $
918333 918336 6 6 DD 1 2 1 2 0 0 $ 1
$1111 916463 $9999 5 5 DD 1 1 1
2 $ 0 $
4108508903 4108508932 10 10 DD 1 2 1 $ 7 0 $ $
4104196006 4104196006 10 10 DD 1 2 7 $ 0 0 $ $
NUMBER OF RANGES 10
ADD
DELETE
MODIFY
OK
CANCEL
HELP
3104
3131

Fig. 93

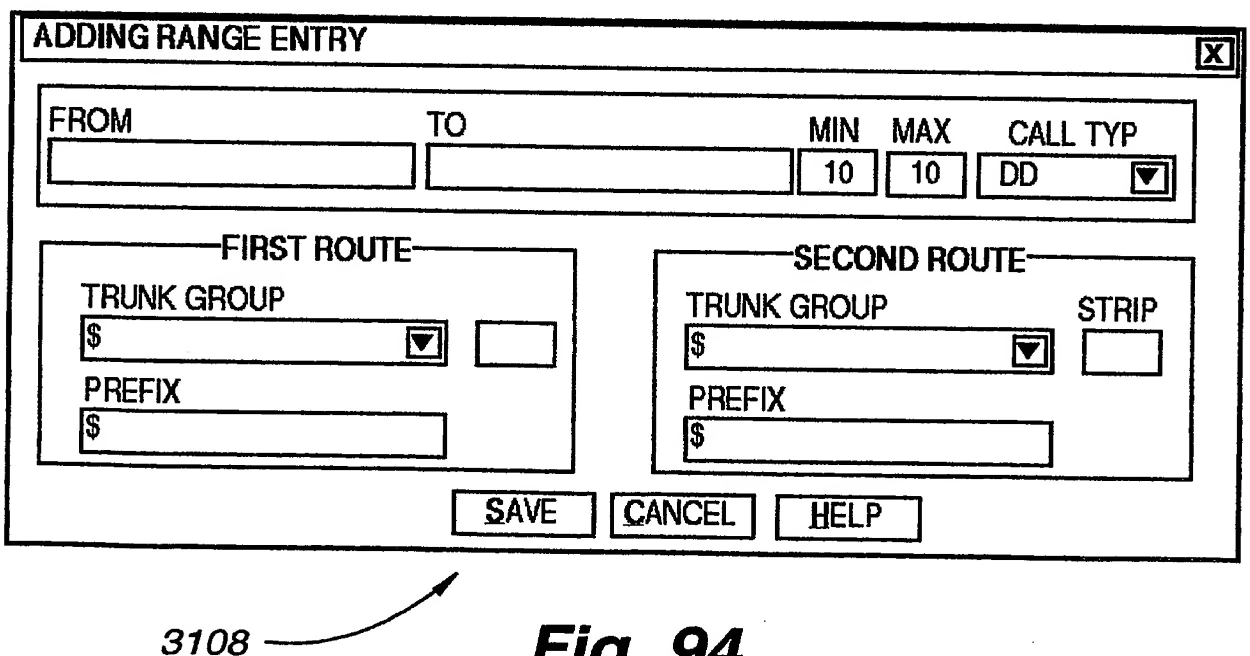
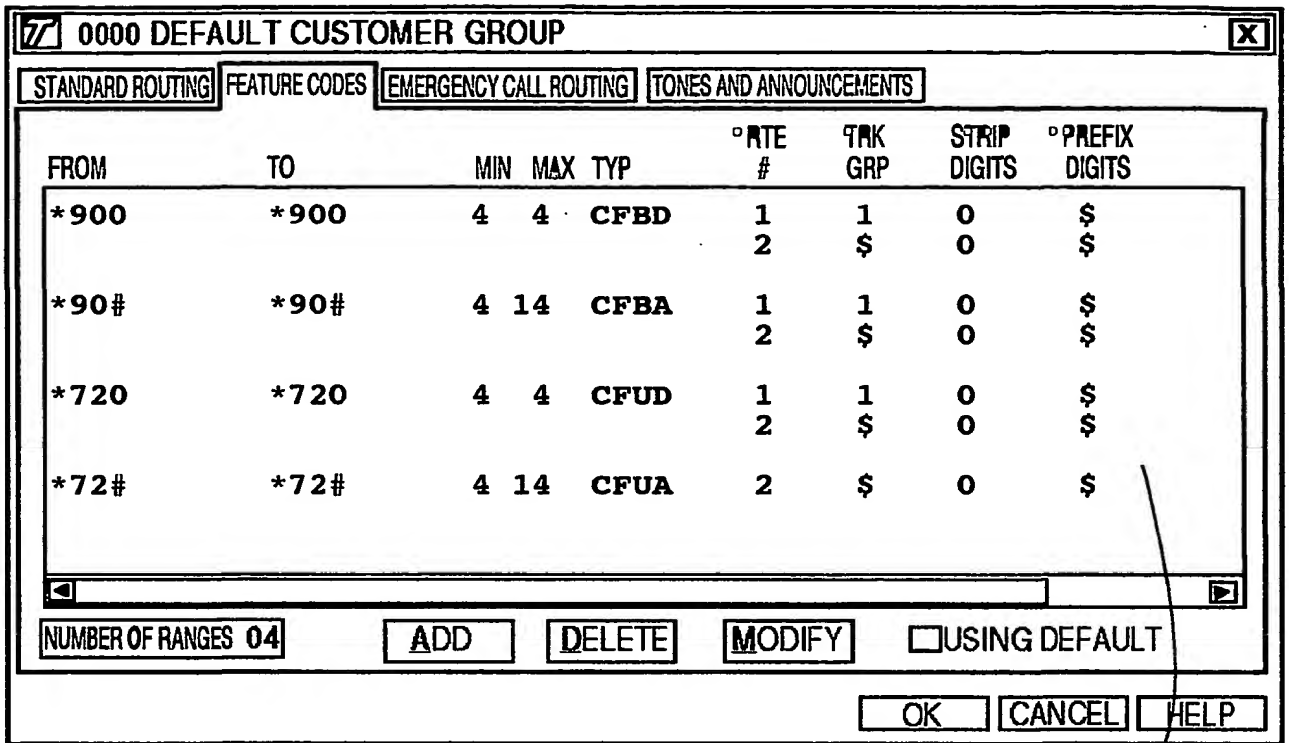

ADDING RANGE ENTRY
FROM
TO
MIN
MAX
CALL TYP
10
10
DD
FIRST ROUTE
TRUNK GROUP
$
PREFIX
$
SECOND ROUTE
TRUNK GROUP
STRIP
$
PREFIX
$
SAVE
CANCEL
HELP
3108

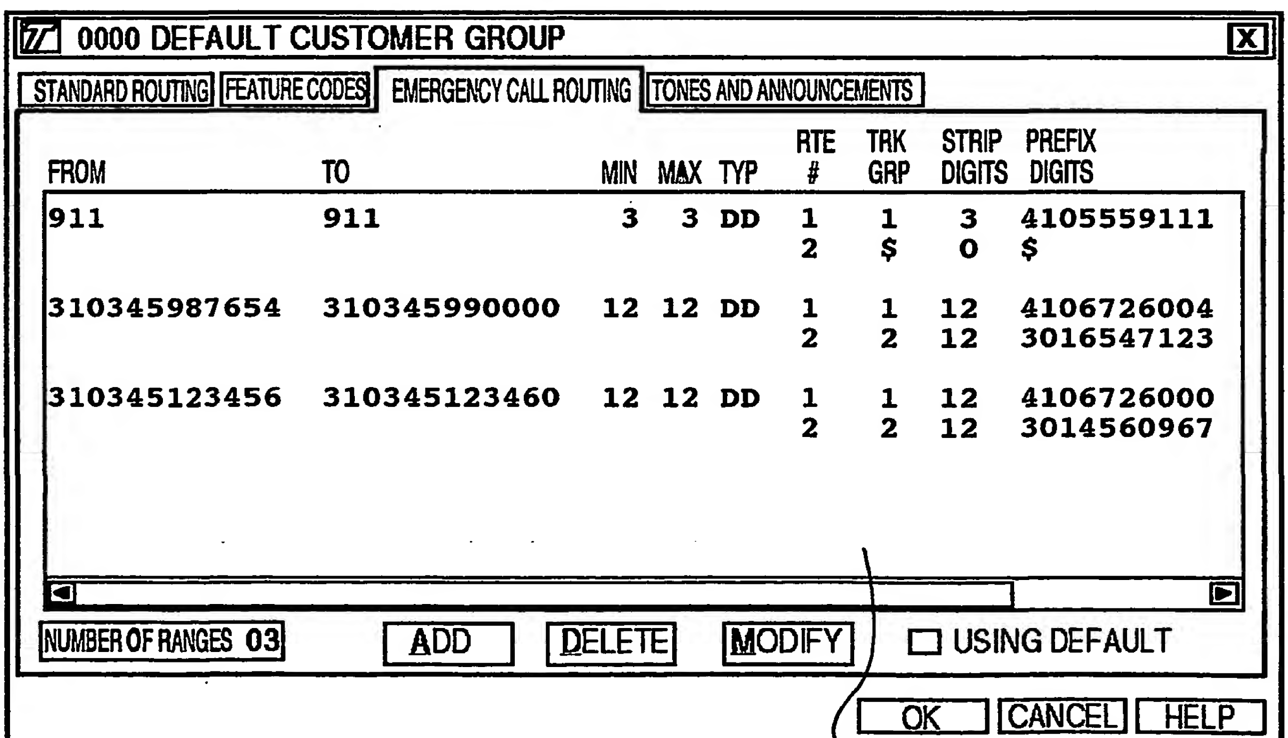
Fig. 94



3105

Fig. 95

3151



3106

Fig. 96

3161

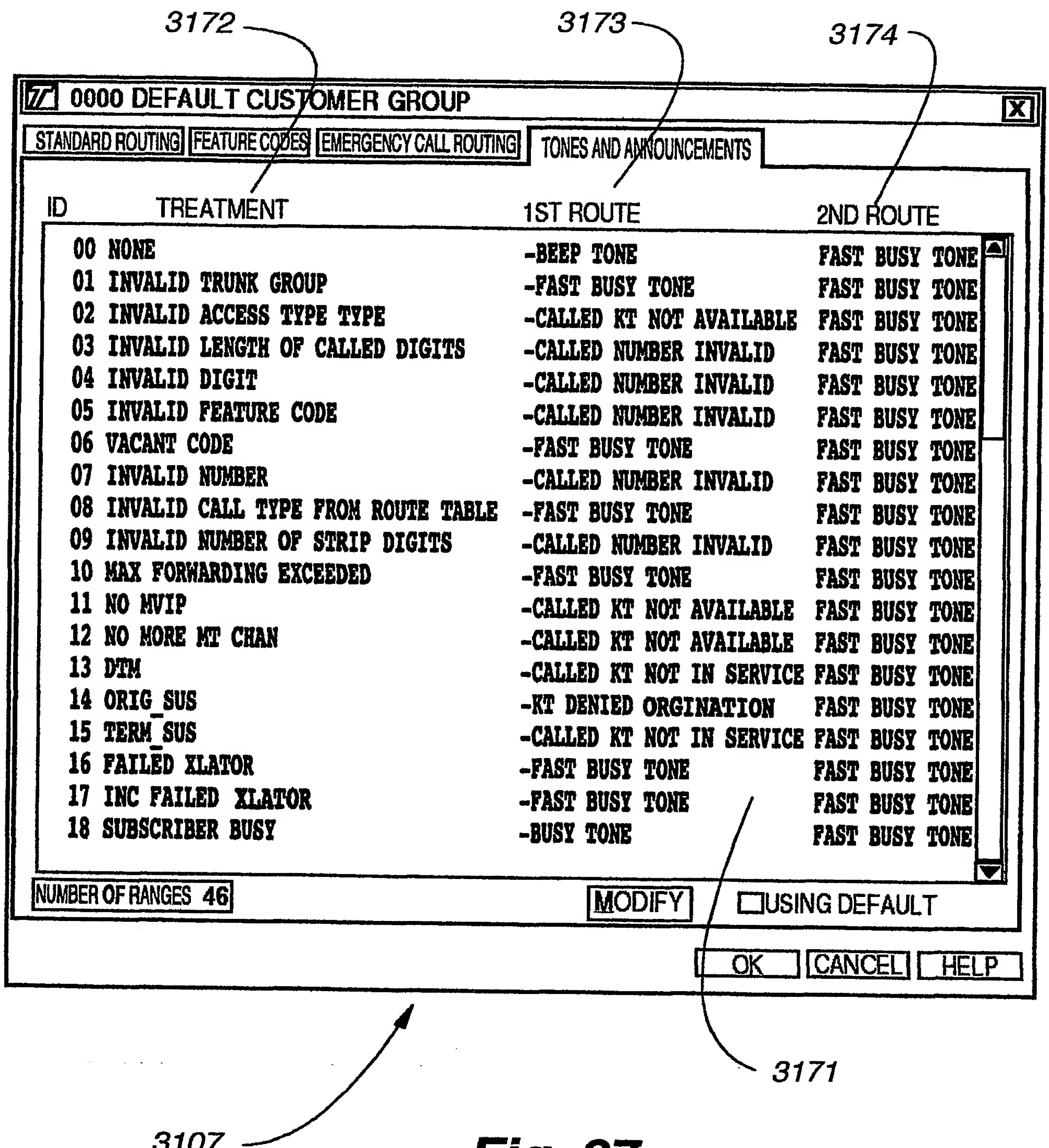

3172
3173
3174
0000 DEFAULT CUSTOMER GROUP
X
STANDARD ROUTING
FEATURE CODES
EMERGENCY CALL ROUTING
TONES AND ANNOUNCEMENTS
ID
TREATMENT
1ST ROUTE
2ND ROUTE
00 NONE -BEEP TONE FAST BUSY TONE
01 INVALID TRUNK GROUP -FAST BUSY TONE FAST BUSY TONE
02 INVALID ACCESS TYPE TYPE -CALLED KT NOT AVAILABLE FAST BUSY TONE
03 INVALID LENGTH OF CALLED DIGITS -CALLED NUMBER INVALID FAST BUSY TONE
04 INVALID DIGIT -CALLED NUMBER INVALID FAST BUSY TONE
05 INVALID FEATURE CODE -CALLED NUMBER INVALID FAST BUSY TONE
06 VACANT CODE -FAST BUSY TONE FAST BUSY TONE
07 INVALID NUMBER -CALLED NUMBER INVALID FAST BUSY TONE
08 INVALID CALL TYPE FROM ROUTE TABLE -FAST BUSY TONE FAST BUSY TONE
09 INVALID NUMBER OF STRIP DIGITS -CALLED NUMBER INVALID FAST BUSY TONE
10 MAX FORWARDING EXCEEDED -FAST BUSY TONE FAST BUSY TONE
11 NO MVIP -CALLED KT NOT AVAILABLE FAST BUSY TONE
12 NO MORE MT CHAN -CALLED KT NOT AVAILABLE FAST BUSY TONE
13 DTM -CALLED KT NOT IN SERVICE FAST BUSY TONE
14 ORIG_SUS -KT DENIED ORGINATION FAST BUSY TONE
15 TERM_SUS -CALLED KT NOT IN SERVICE FAST BUSY TONE
16 FAILED XLATOR -FAST BUSY TONE FAST BUSY TONE
17 INC FAILED XLATOR -FAST BUSY TONE FAST BUSY TONE
18 SUBSCRIBER BUSY -BUSY TONE FAST BUSY TONE
NUMBER OF RANGES 46
MODIFY
USING DEFAULT
OK
CANCEL
HELP
3171
3107

Fig. 97

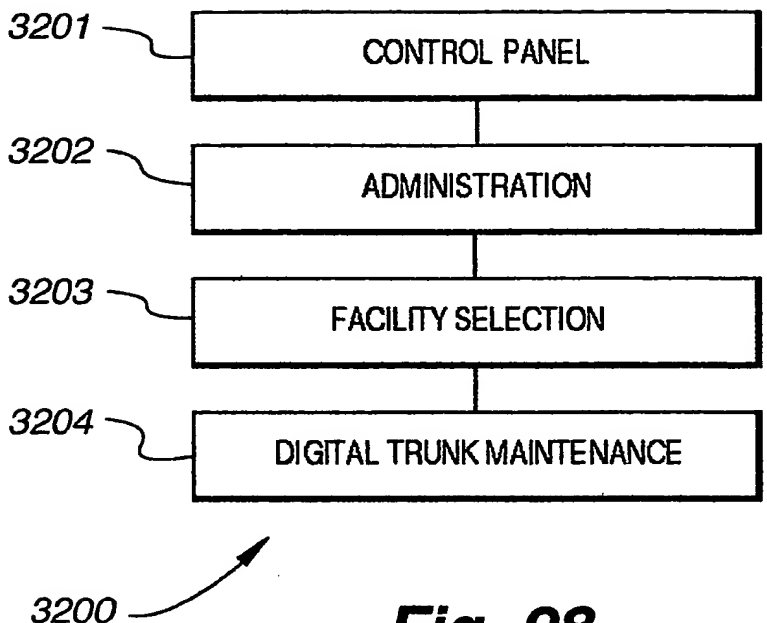

3201
CONTROL PANEL
3202
ADMINISTRATION
3203
FACILITY SELECTION
3204
DIGITAL TRUNK MAINTENANCE
3200

Fig. 98

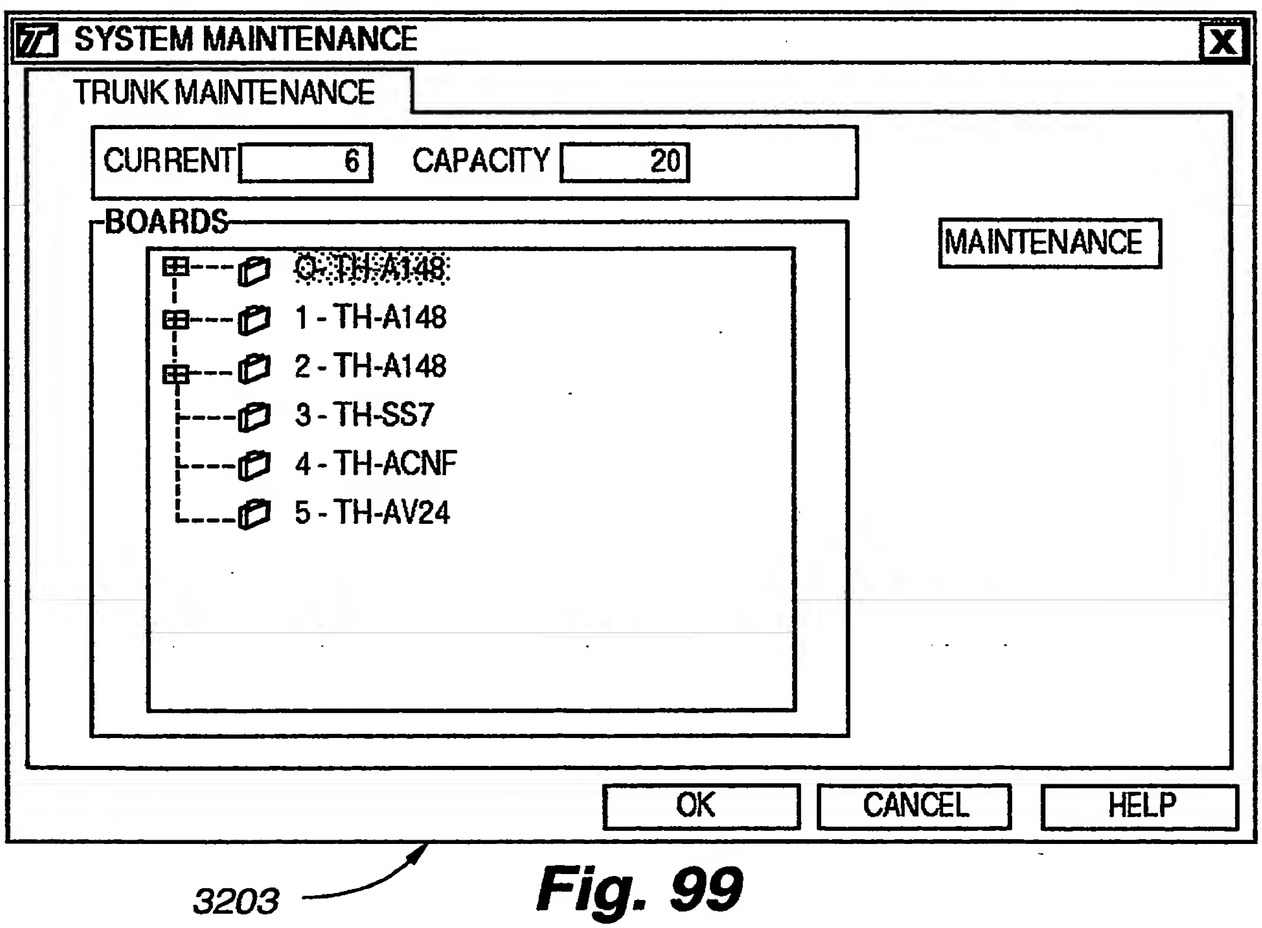
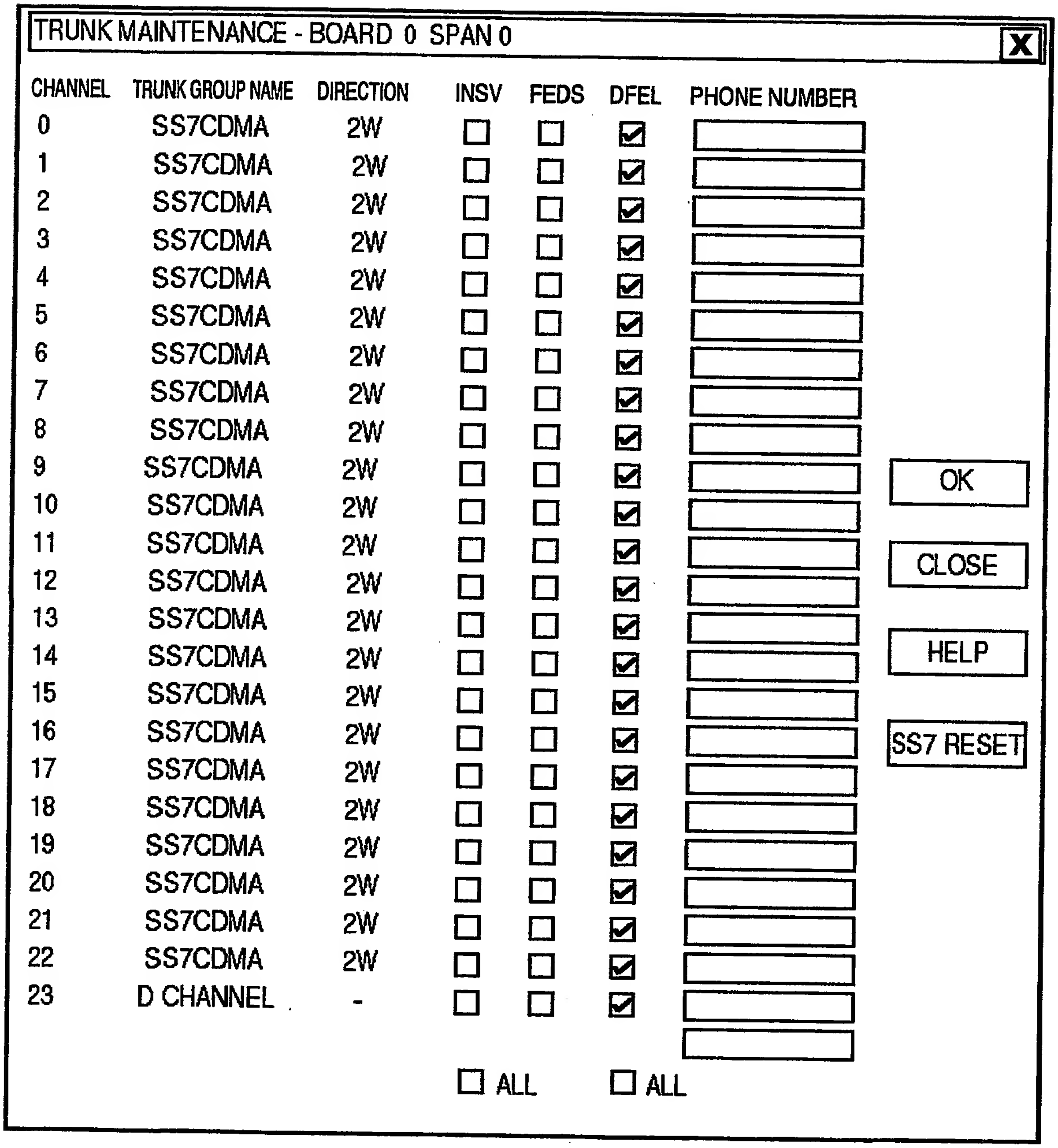

SYSTEM MAINTENANCE
X
TRUNK MAINTENANCE
CURRENT 6
CAPACITY 20
BOARDS
0 - TH-A148
1 - TH-A148
2 - TH-A148
3 - TH-SS7
4 - TH-ACNF
5 - TH-AV24
MAINTENANCE
OK
CANCEL
HELP
3203

Fig. 99


TRUNK MAINTENANCE - BOARD 0 SPAN 0
X
CHANNEL
TRUNK GROUP NAME
DIRECTION
INSV
FEDS
DFEL
PHONE NUMBER
0 SS7CDMA 2W
1 SS7CDMA 2W
2 SS7CDMA 2W
3 SS7CDMA 2W
4 SS7CDMA 2W
5 SS7CDMA 2W
6 SS7CDMA 2W
7 SS7CDMA 2W
8 SS7CDMA 2W
9 SS7CDMA 2W
10 SS7CDMA 2W
11 SS7CDMA 2W
12 SS7CDMA 2W
13 SS7CDMA 2W
14 SS7CDMA 2W
15 SS7CDMA 2W
16 SS7CDMA 2W
17 SS7CDMA 2W
18 SS7CDMA 2W
19 SS7CDMA 2W
20 SS7CDMA 2W
21 SS7CDMA 2W
22 SS7CDMA 2W
23 D CHANNEL -
ALL
ALL
OK
CLOSE
HELP
SS7 RESET

3204

Fig. 100

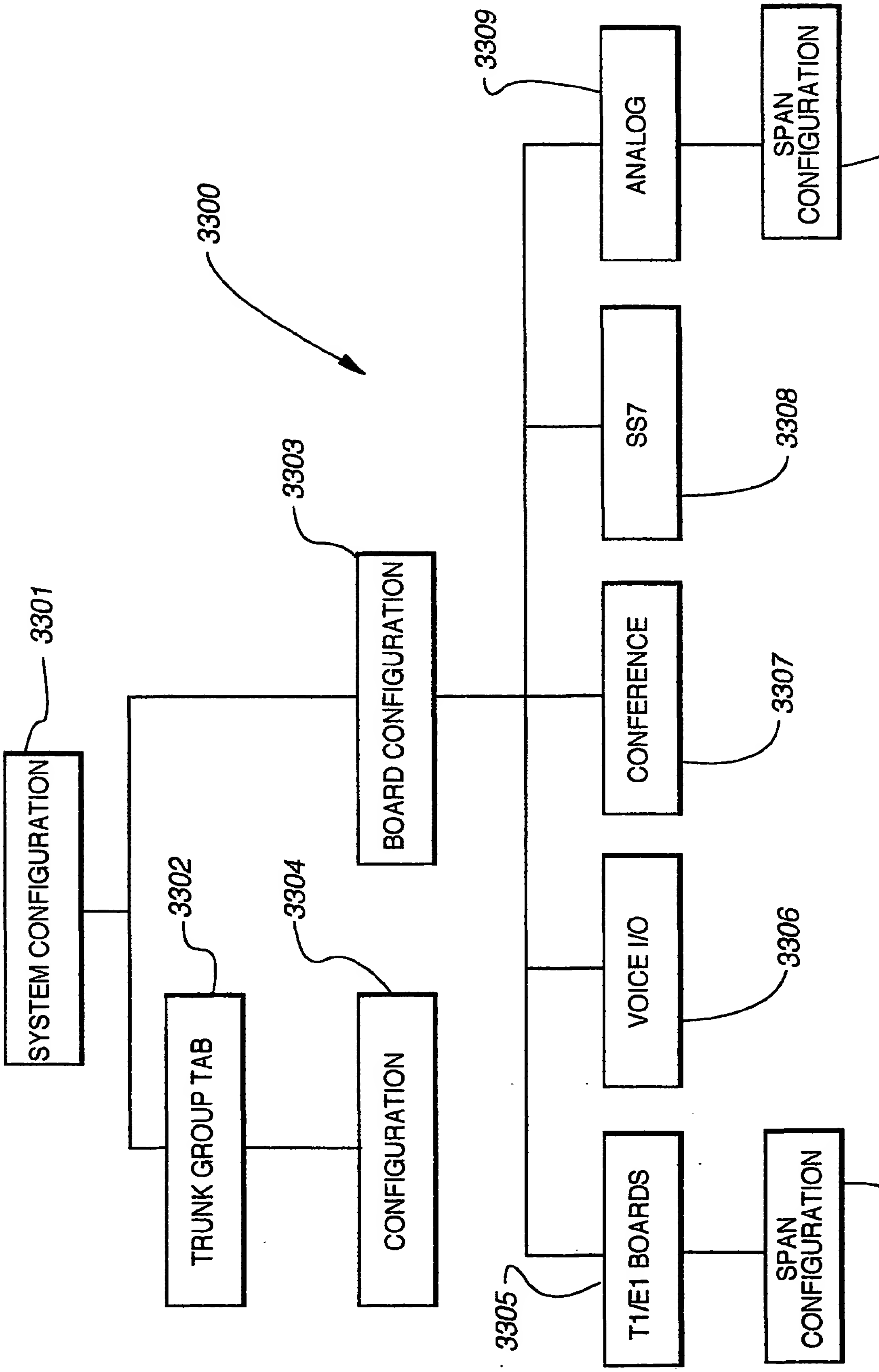

3300
SYSTEM CONFIGURATION
3301
TRUNK GROUP TAB
3302
BOARD CONFIGURATION
3303
CONFIGURATION
3304
T1/E1 BOARDS
3305
VOICE I/O
3306
CONFERENCE
3307
SS7
3308
ANALOG
3309
SPAN CONFIGURATION
3310
SPAN CONFIGURATION
3312

Fig. 101

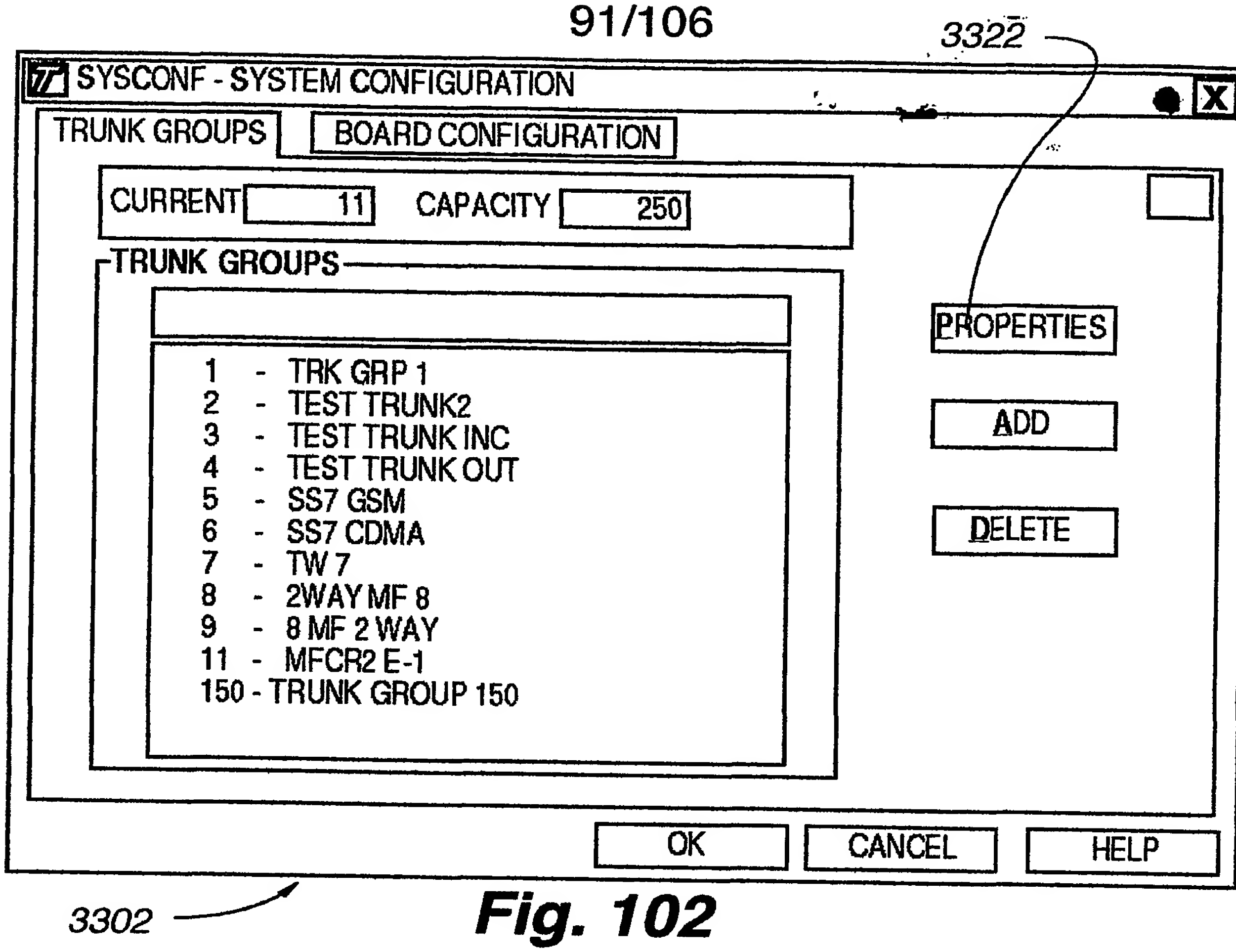


Fig. 102

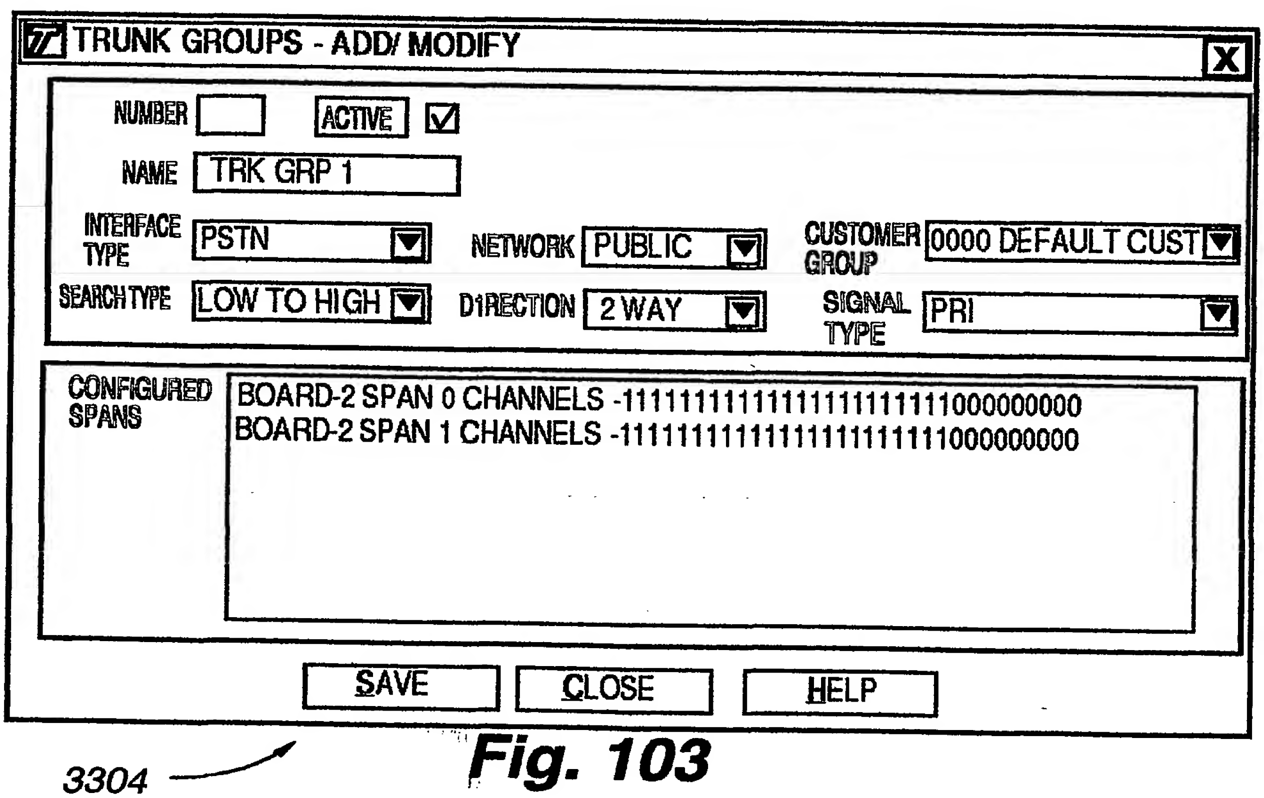


Fig. 103

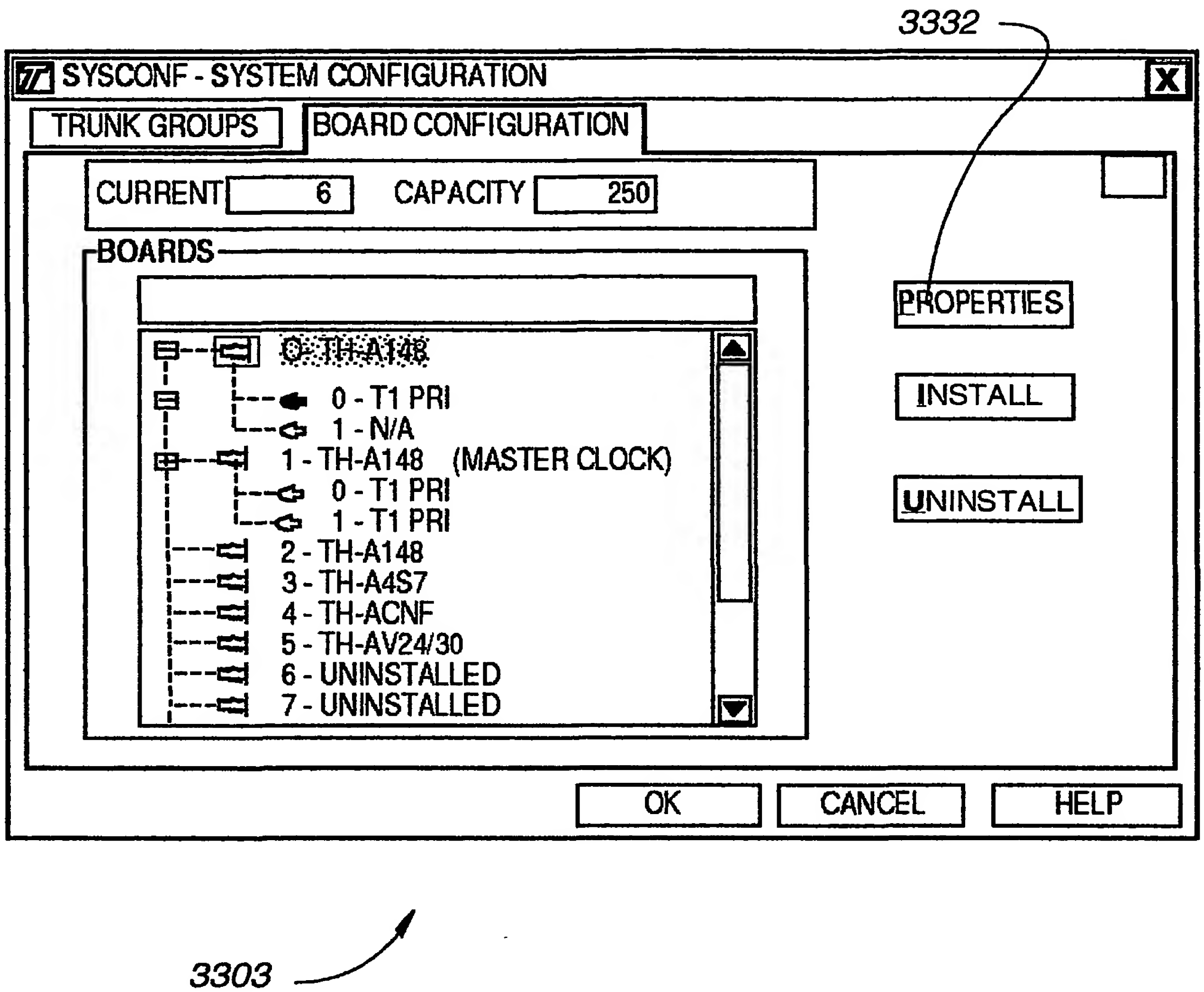

3332
SYSCONF - SYSTEM CONFIGURATION
X
TRUNK GROUPS
BOARD CONFIGURATION
CURRENT
6
CAPACITY
250
BOARDS
0 - TH-A148
0 - T1 PRI
1 - N/A
1 - TH-A148 (MASTER CLOCK)
0 - T1 PRI
1 - T1 PRI
2 - TH-A148
3 - TH-A4S7
4 - TH-ACNF
5 - TH-AV24/30
6 - UNINSTALLED
7 - UNINSTALLED
PROPERTIES
INSTALL
UNINSTALL
OK
CANCEL
HELP
3303

Fig. 104

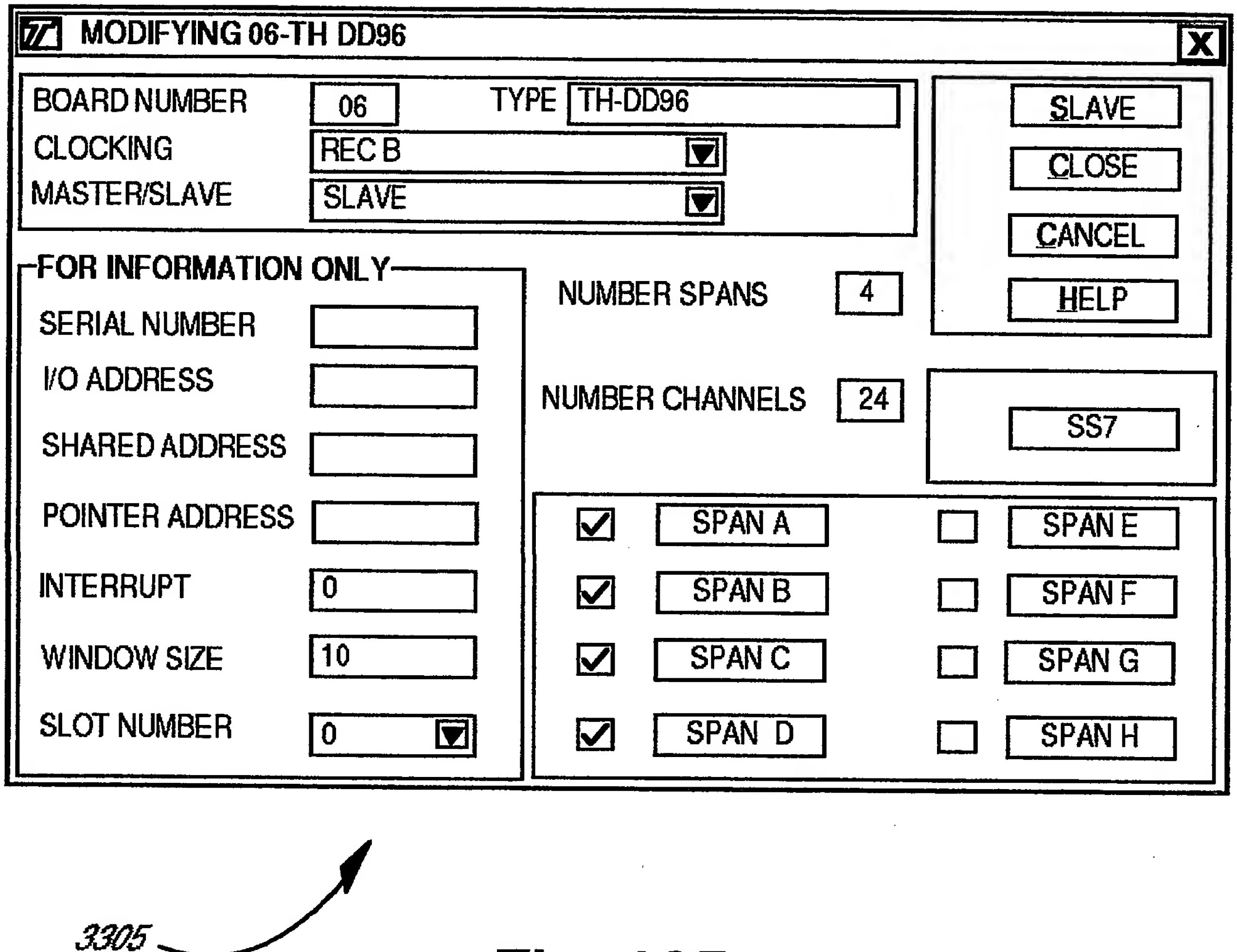

MODIFYING 06-TH DD96
BOARD NUMBER
06
TYPE
TH-DD96
CLOCKING
REC B
MASTER/SLAVE
SLAVE
SLAVE
CLOSE
CANCEL
HELP
FOR INFORMATION ONLY
SERIAL NUMBER
I/O ADDRESS
SHARED ADDRESS
POINTER ADDRESS
INTERRUPT
0
WINDOW SIZE
10
SLOT NUMBER
0
NUMBER SPANS
4
NUMBER CHANNELS
24
SS7
SPAN A
SPAN B
SPAN C
SPAN D
SPAN E
SPAN F
SPAN G
SPAN H
3305

Fig. 105

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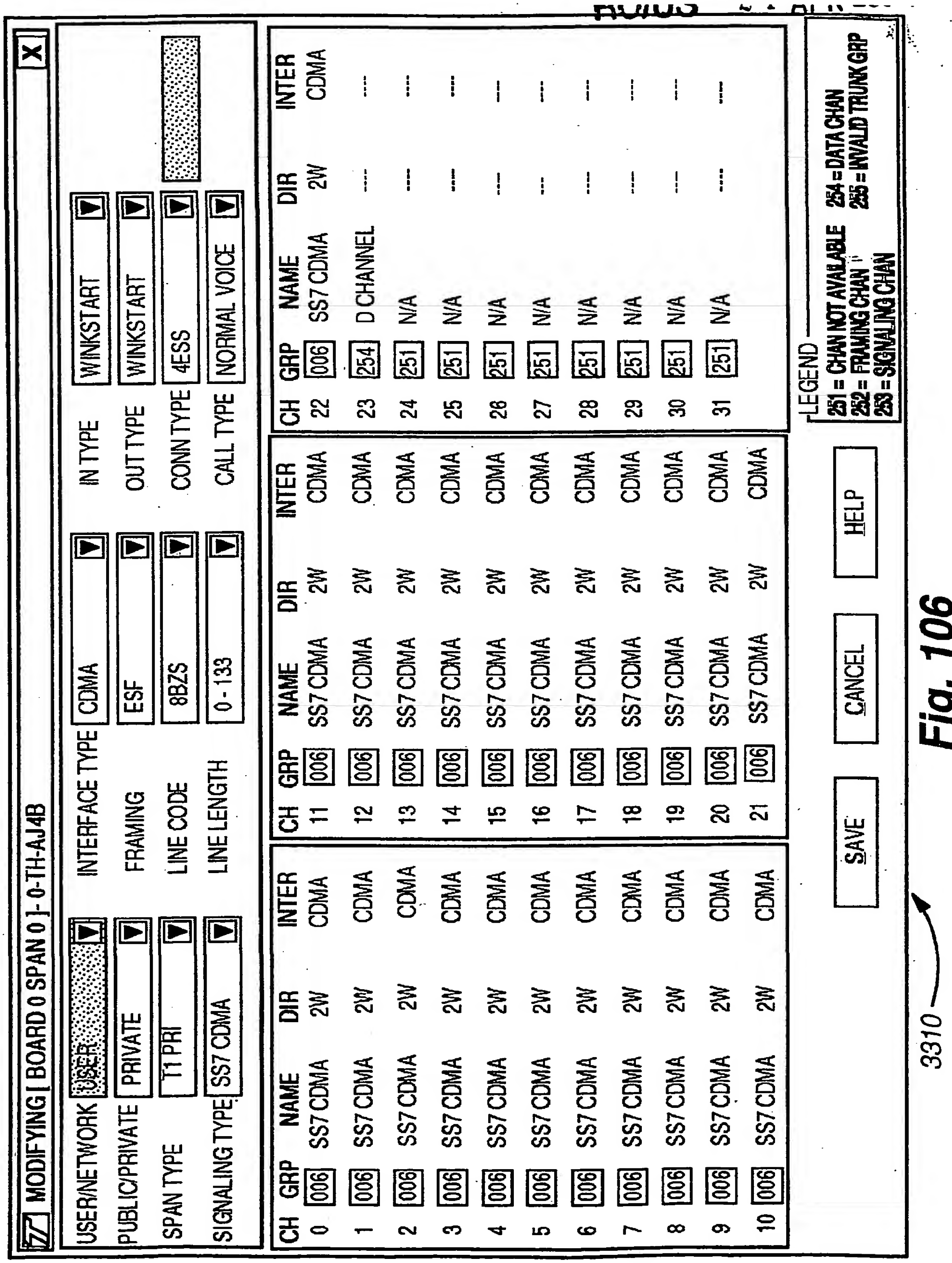

Fig. 106

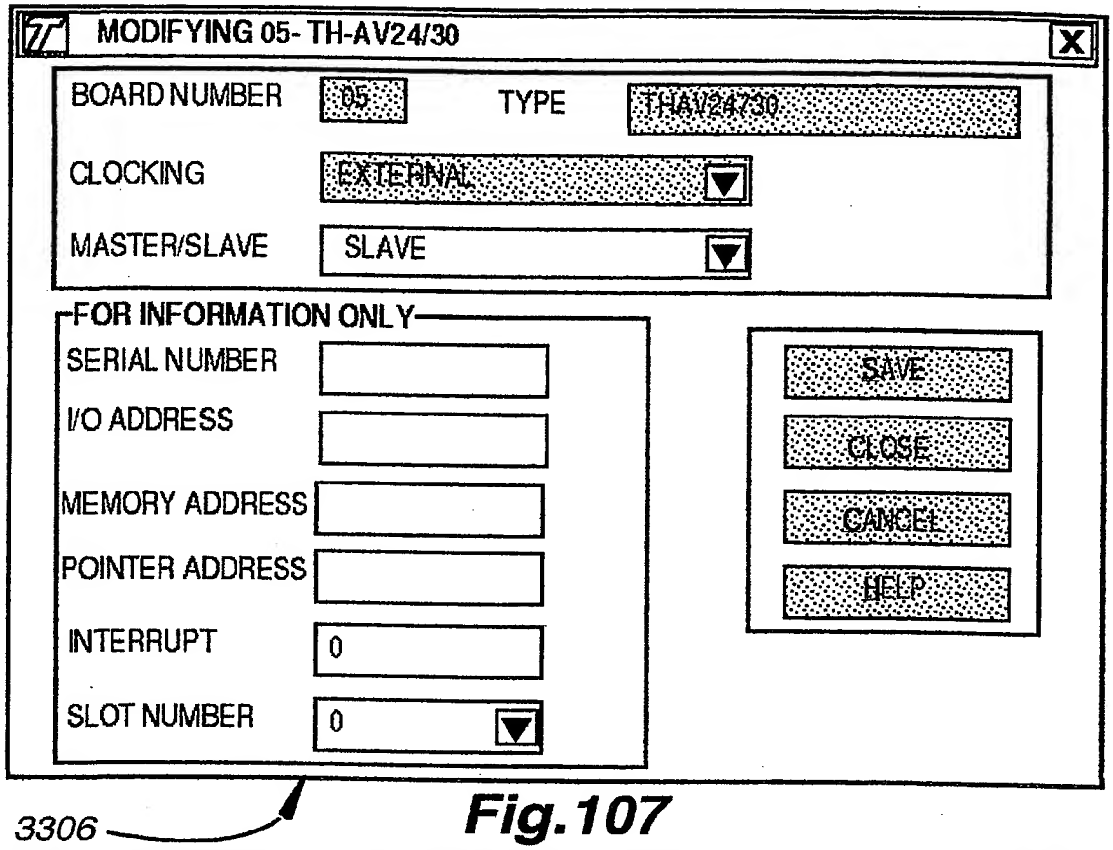

Fig.107

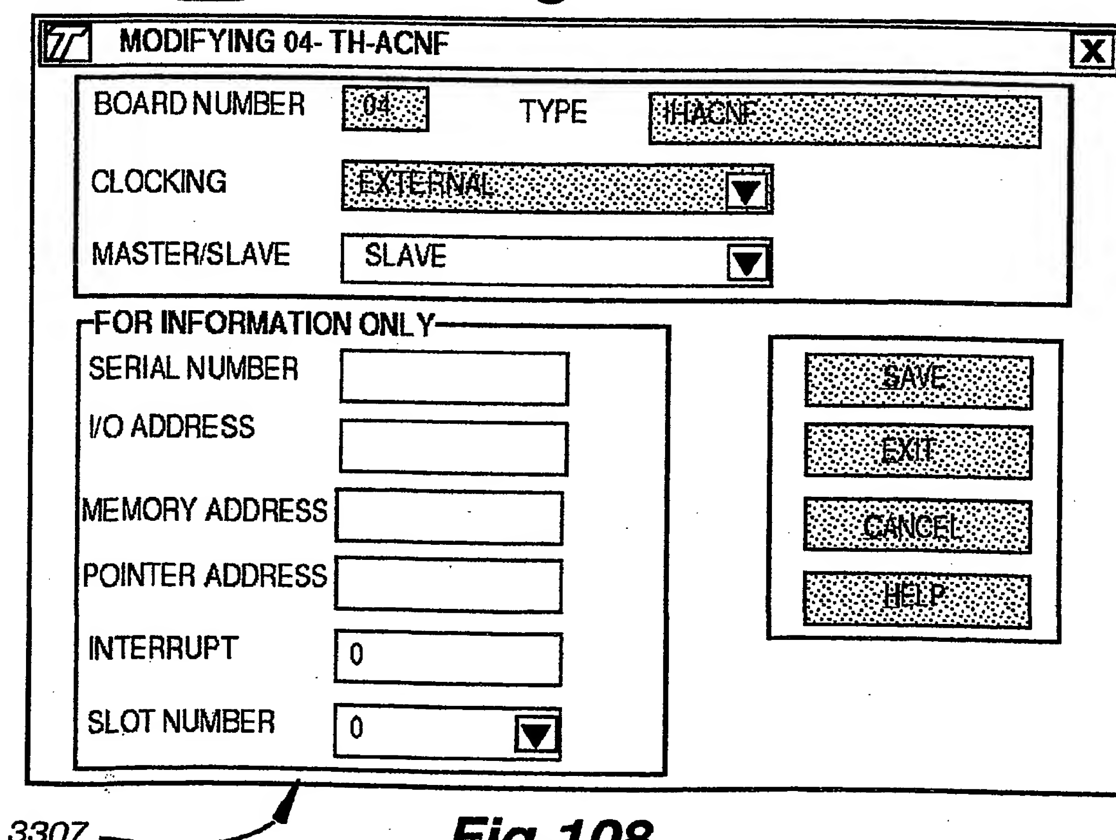

Fig.108

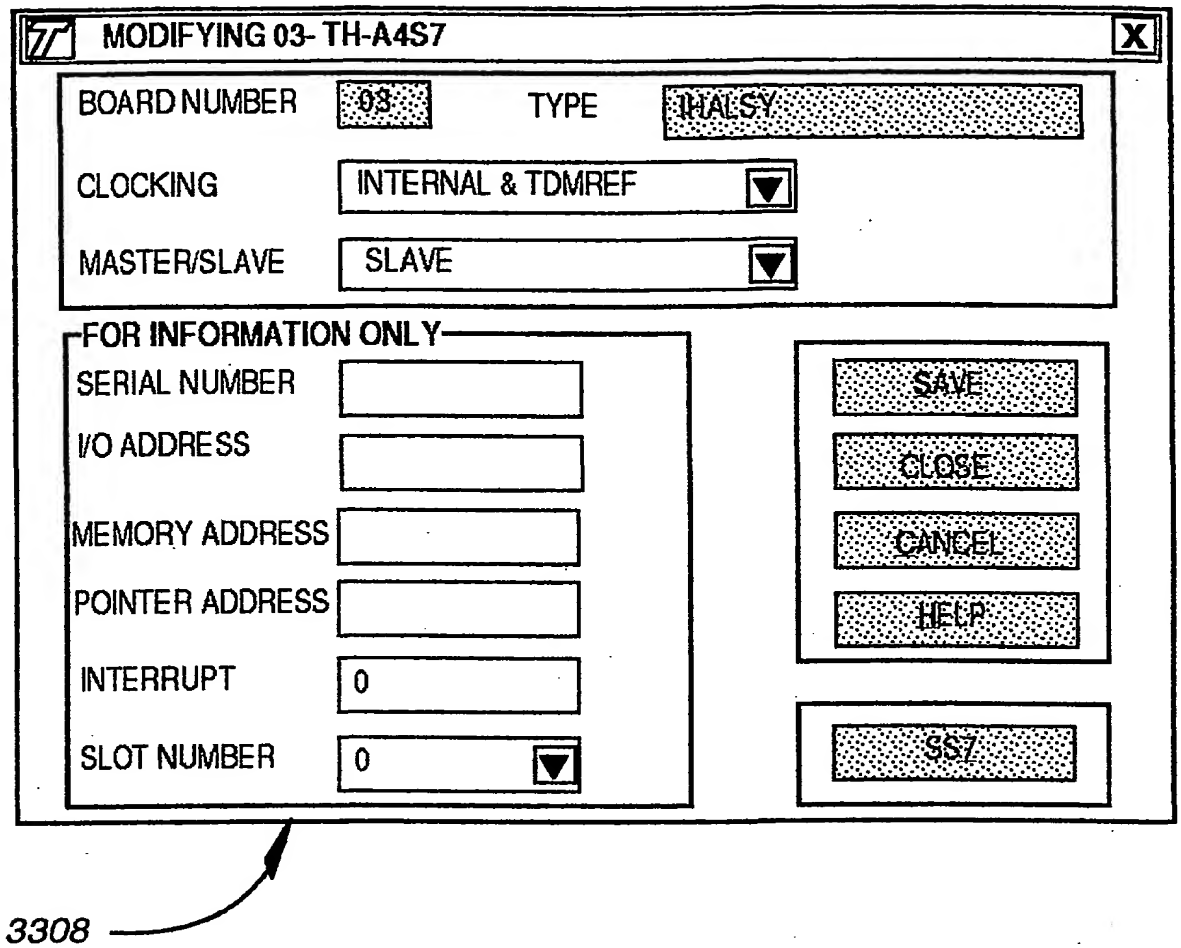
MODIFYING 03- TH-A4S7
X
BOARD NUMBER
03
TYPE
IHALSY
CLOCKING
INTERNAL & TDMREF
MASTER/SLAVE
SLAVE
FOR INFORMATION ONLY
SERIAL NUMBER
I/O ADDRESS
MEMORY ADDRESS
POINTER ADDRESS
INTERRUPT
0
SLOT NUMBER
0
SAVE
CLOSE
CANCEL
HELP
SS7
3308

Fig.109

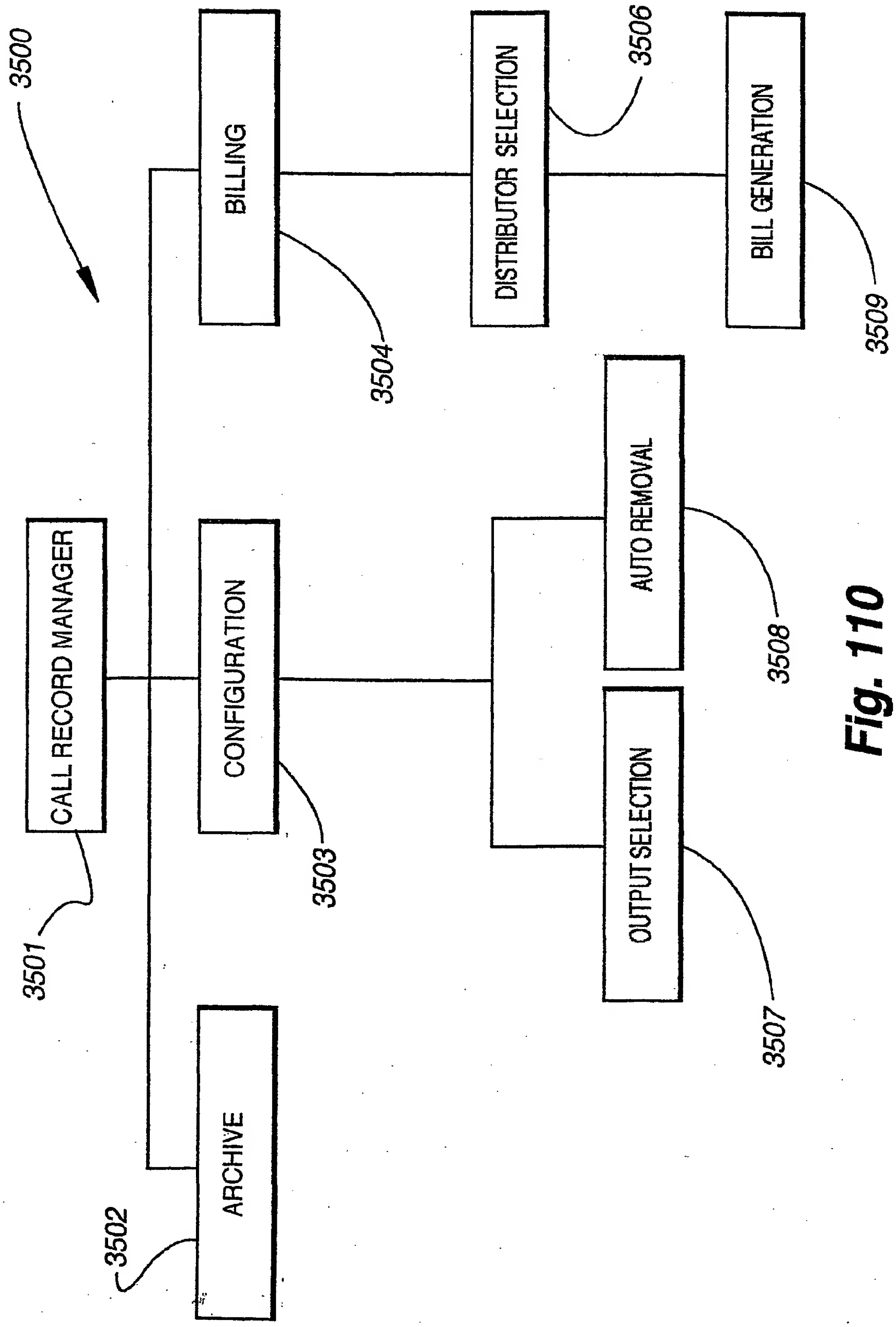
3500
BILLING
3504
DISTRIBUTOR SELECTION
3506
BILL GENERATION
3509
CALL RECORD MANAGER
3501
CONFIGURATION
3503
AUTO REMOVAL
3508
OUTPUT SELECTION
3507
ARCHIVE
3502

Fig. 110

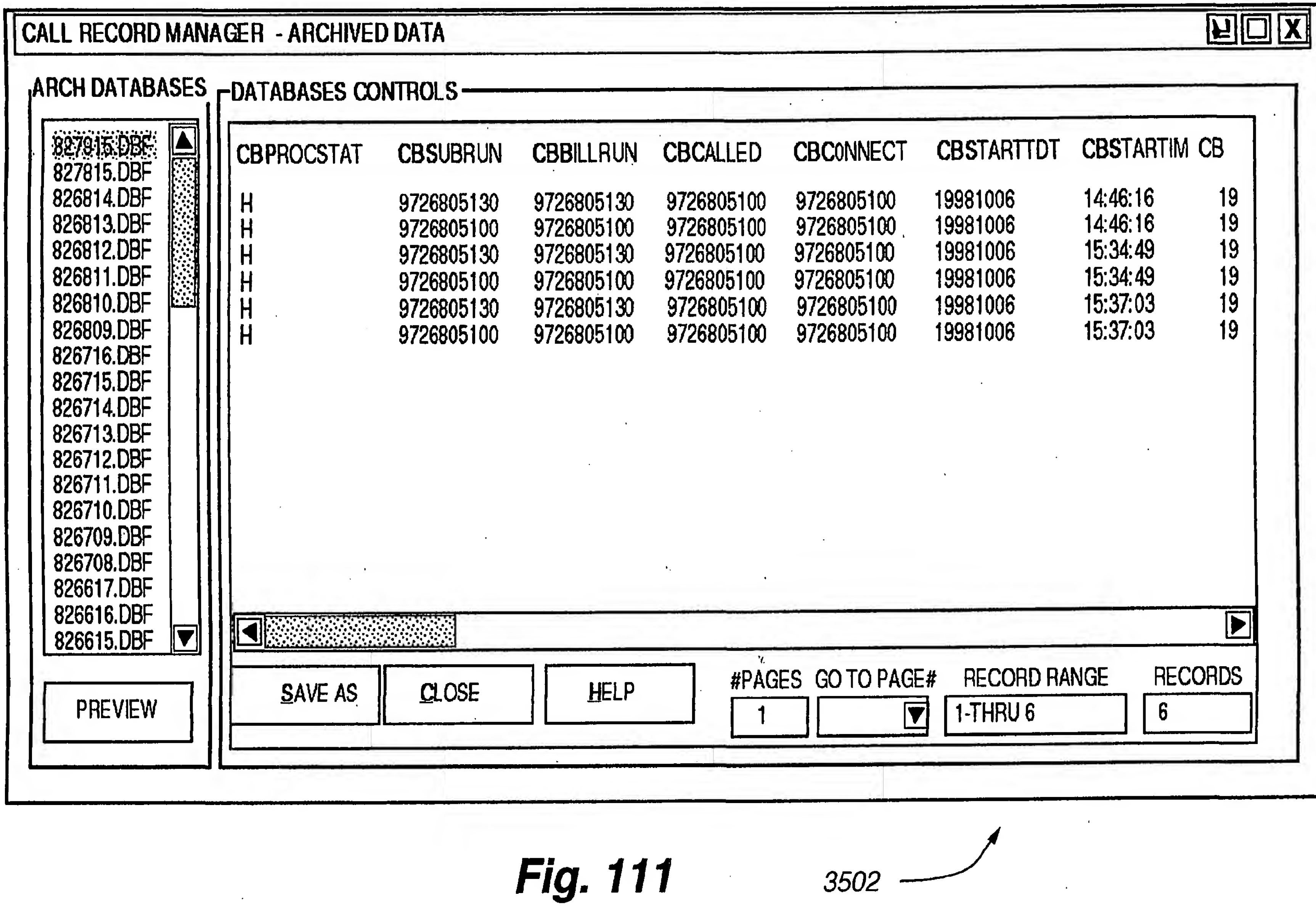
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Fig. 111

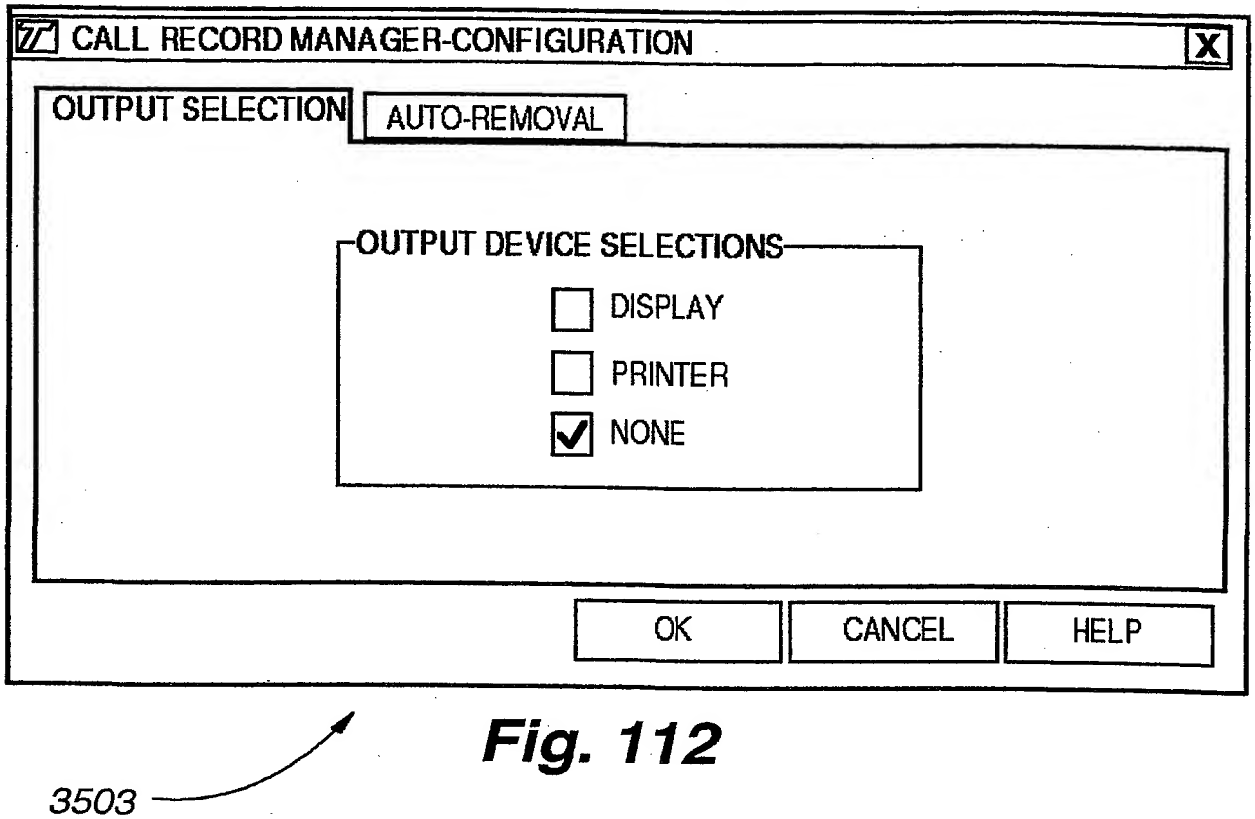

Fig. 112

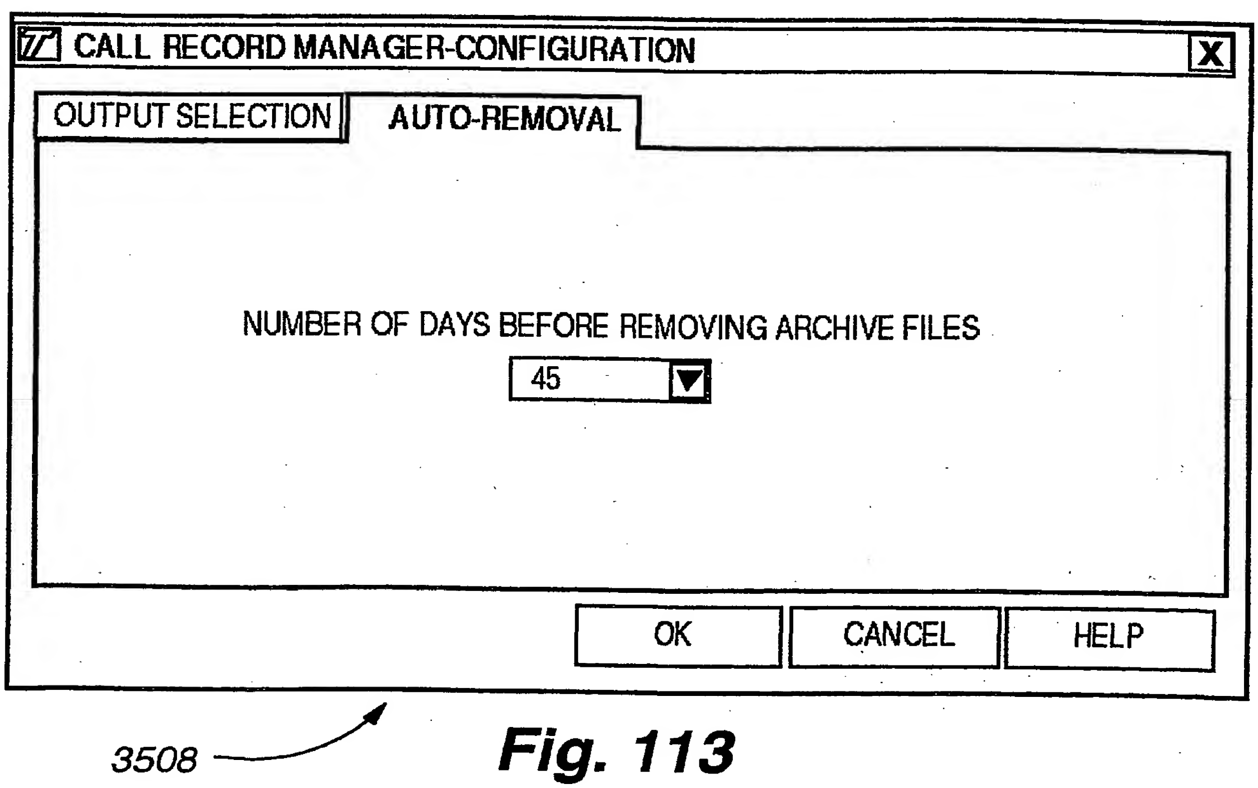

Fig. 113

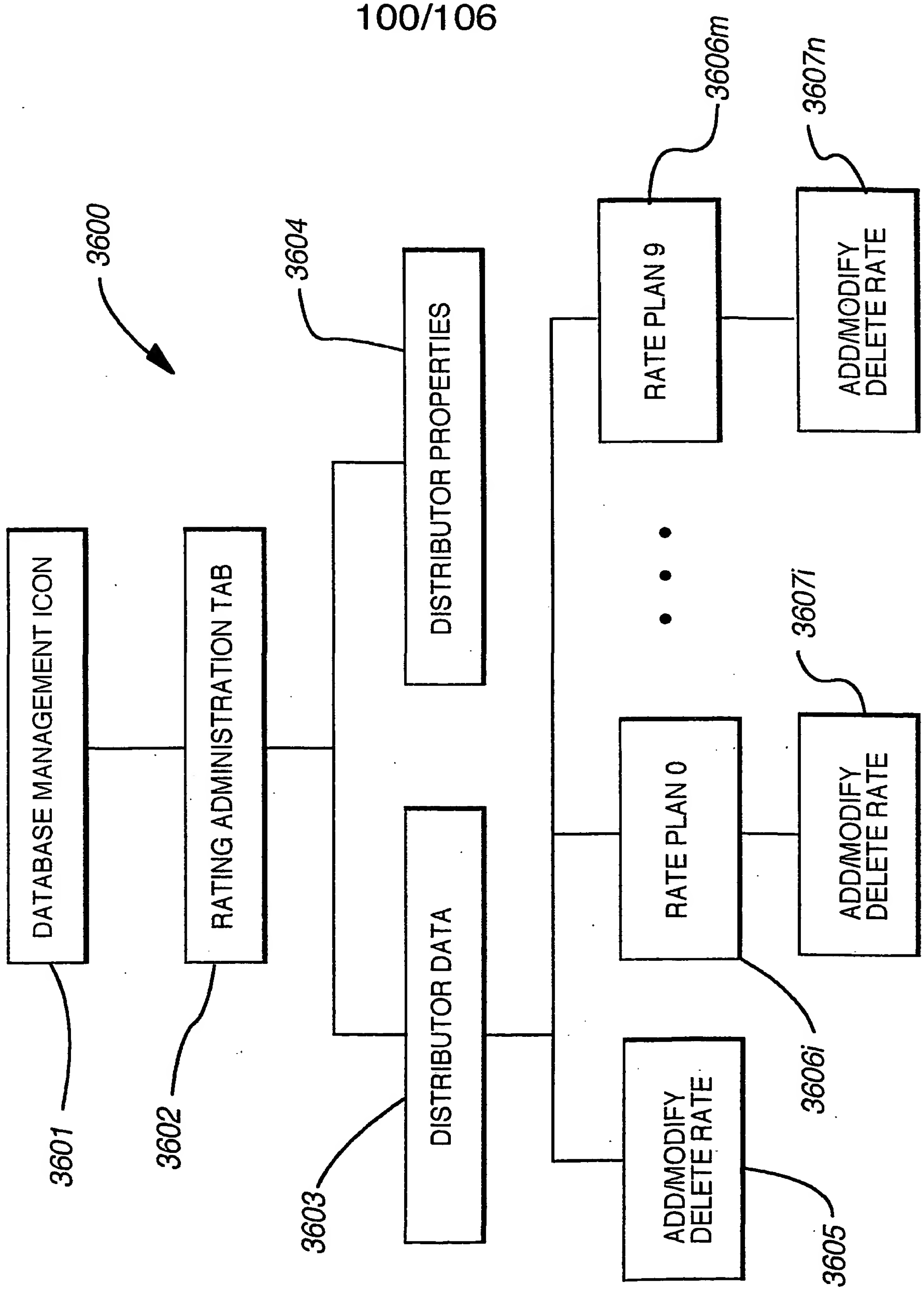
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Fig. 114

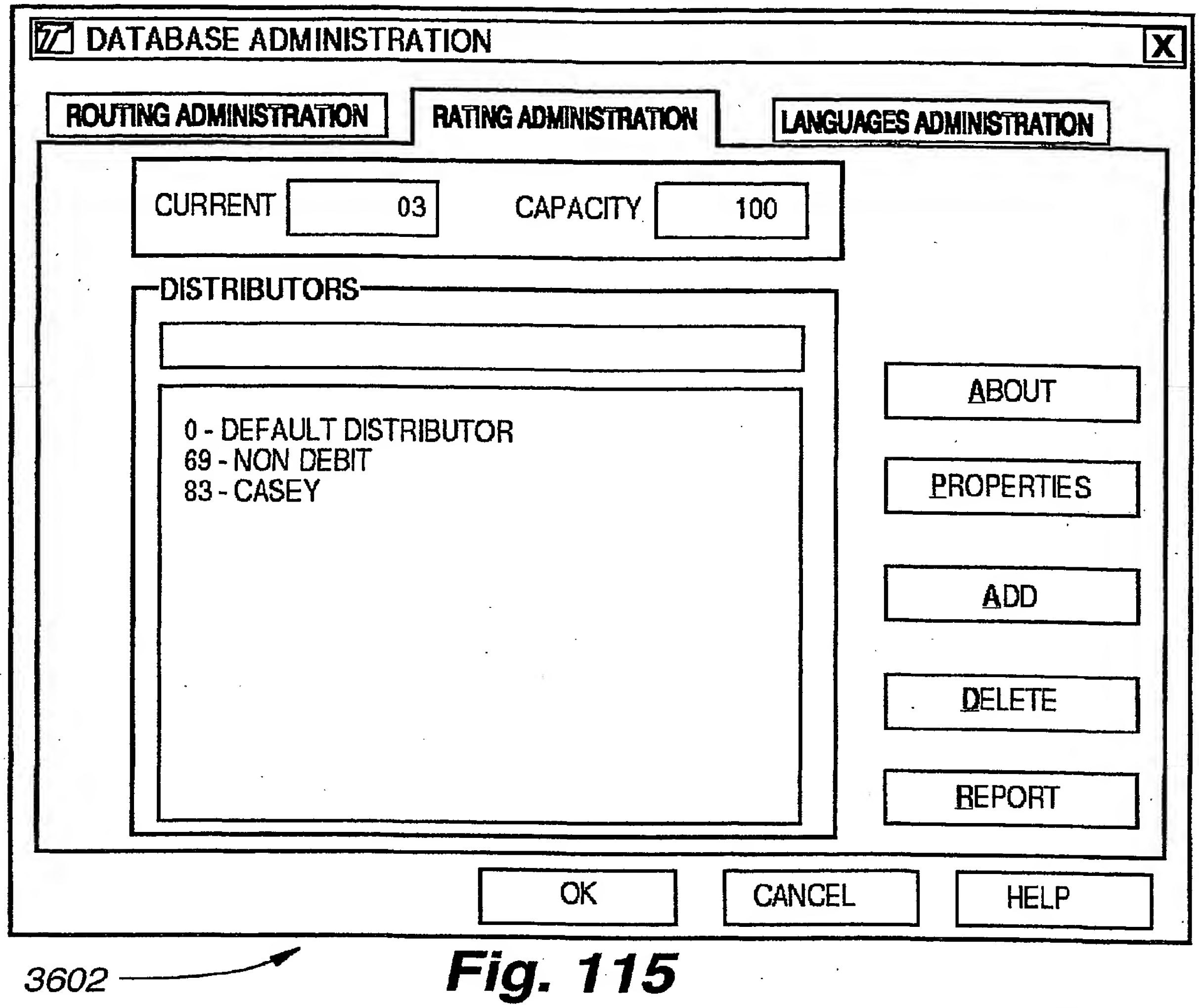


Fig. 115

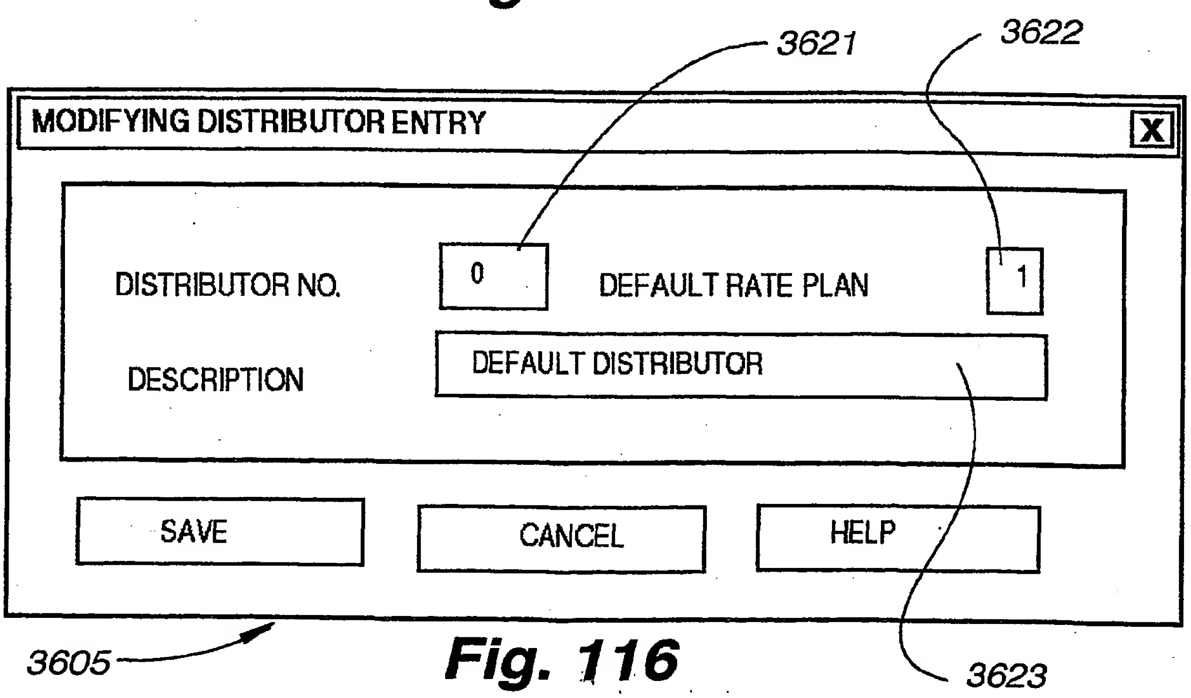
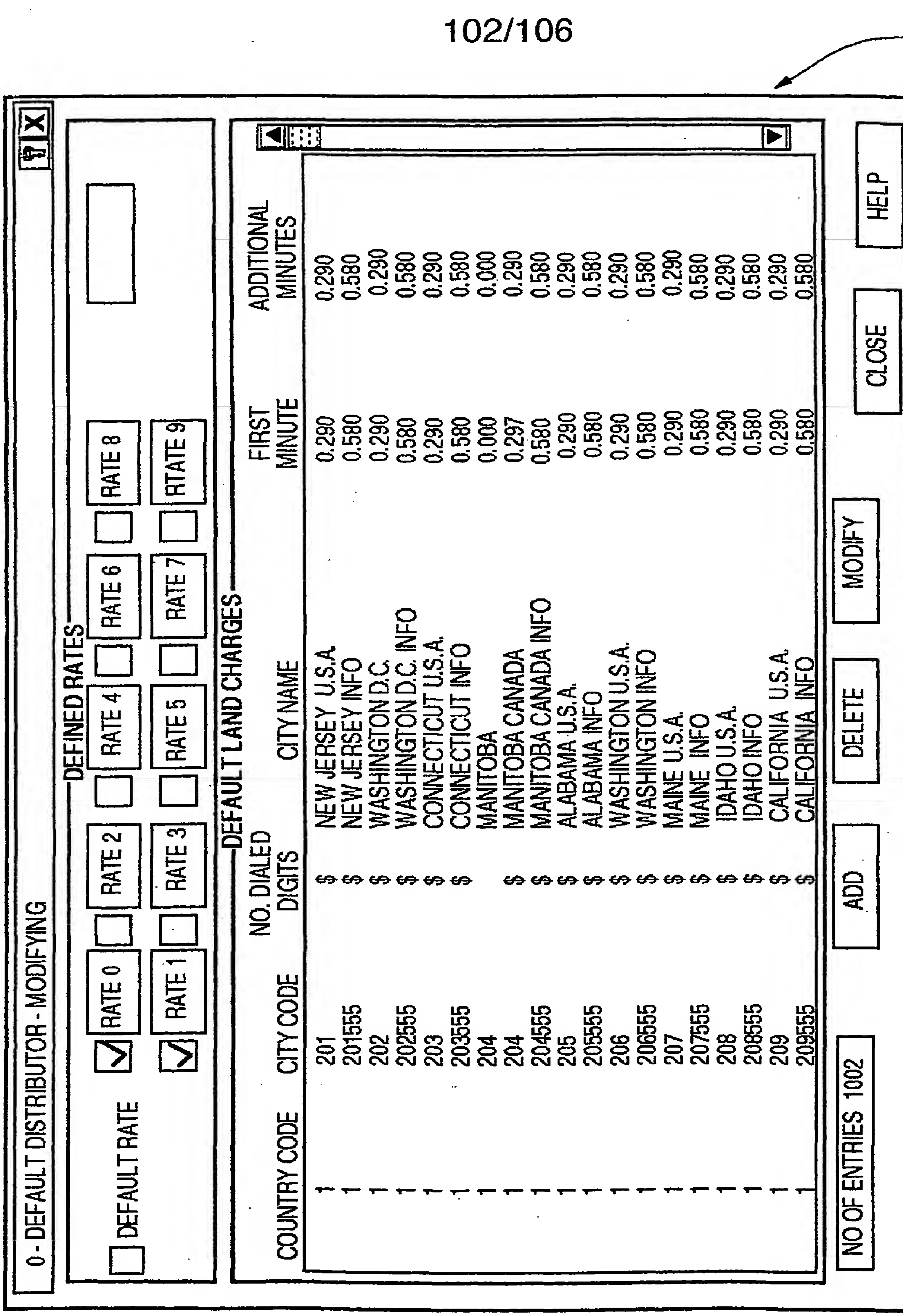


Fig. 116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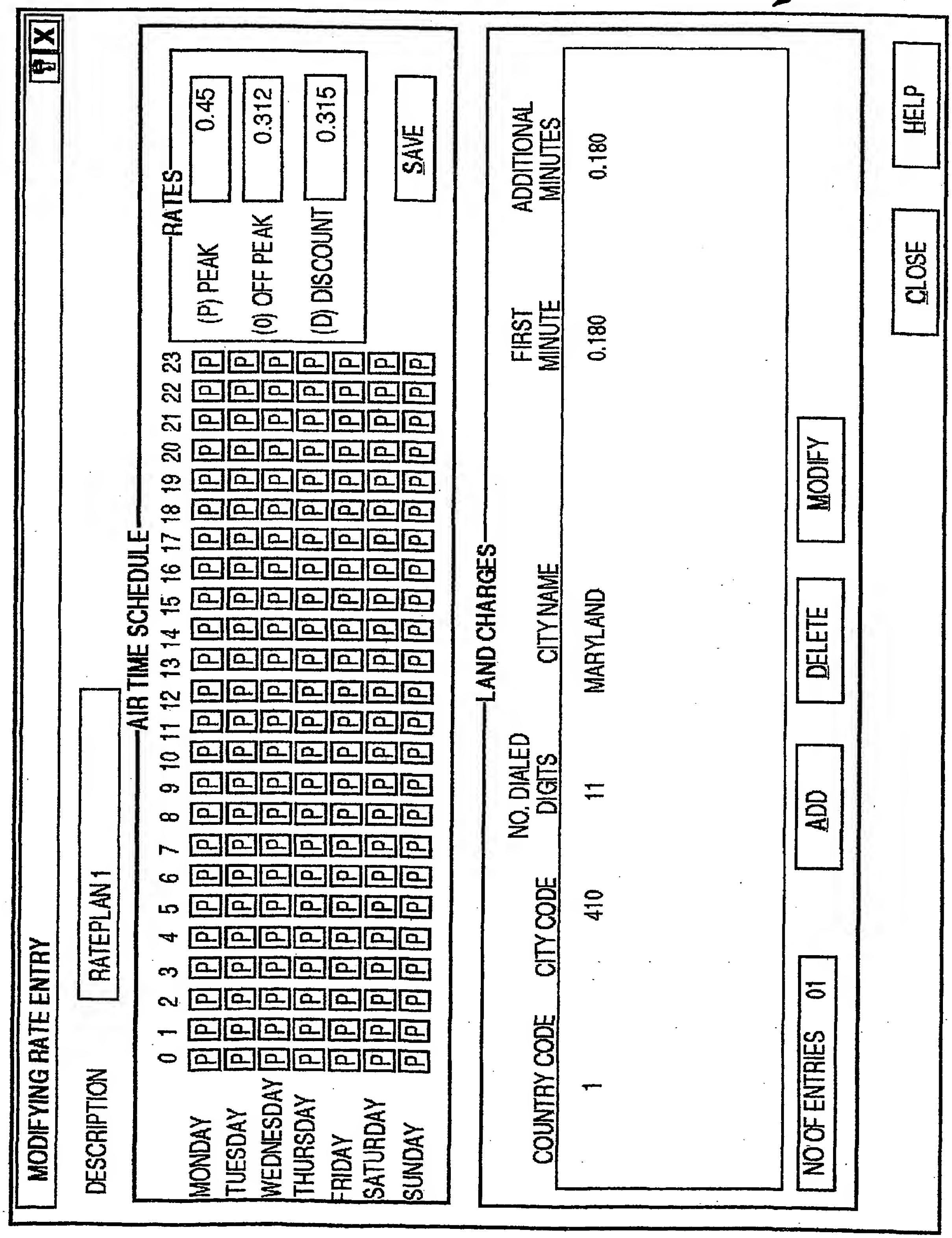
HELP

Fig. 117

3607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SATURDAY
SUNDAY
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CLOSE
HELP

Fig. 118

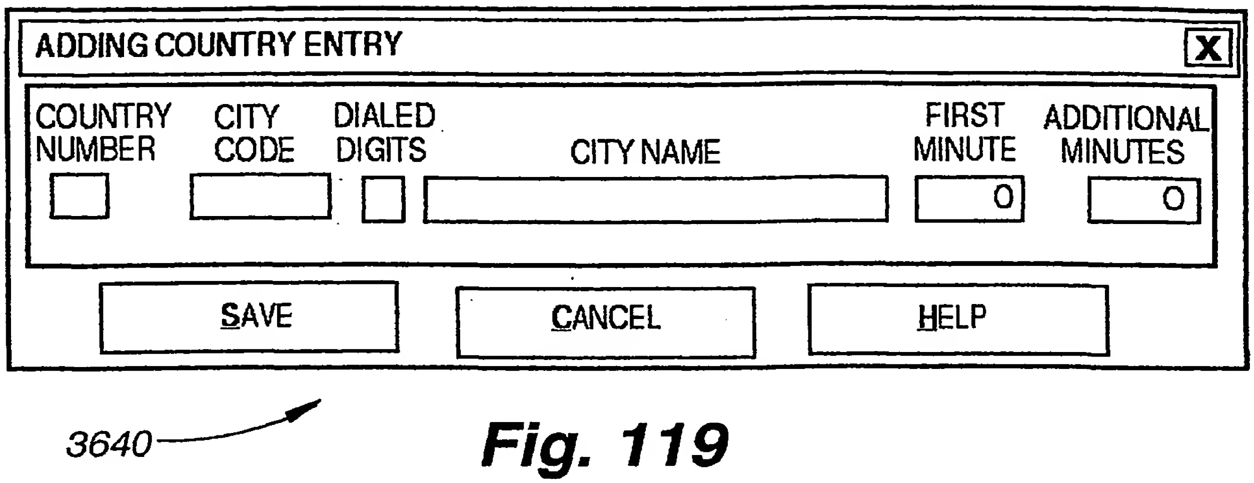


Fig. 119

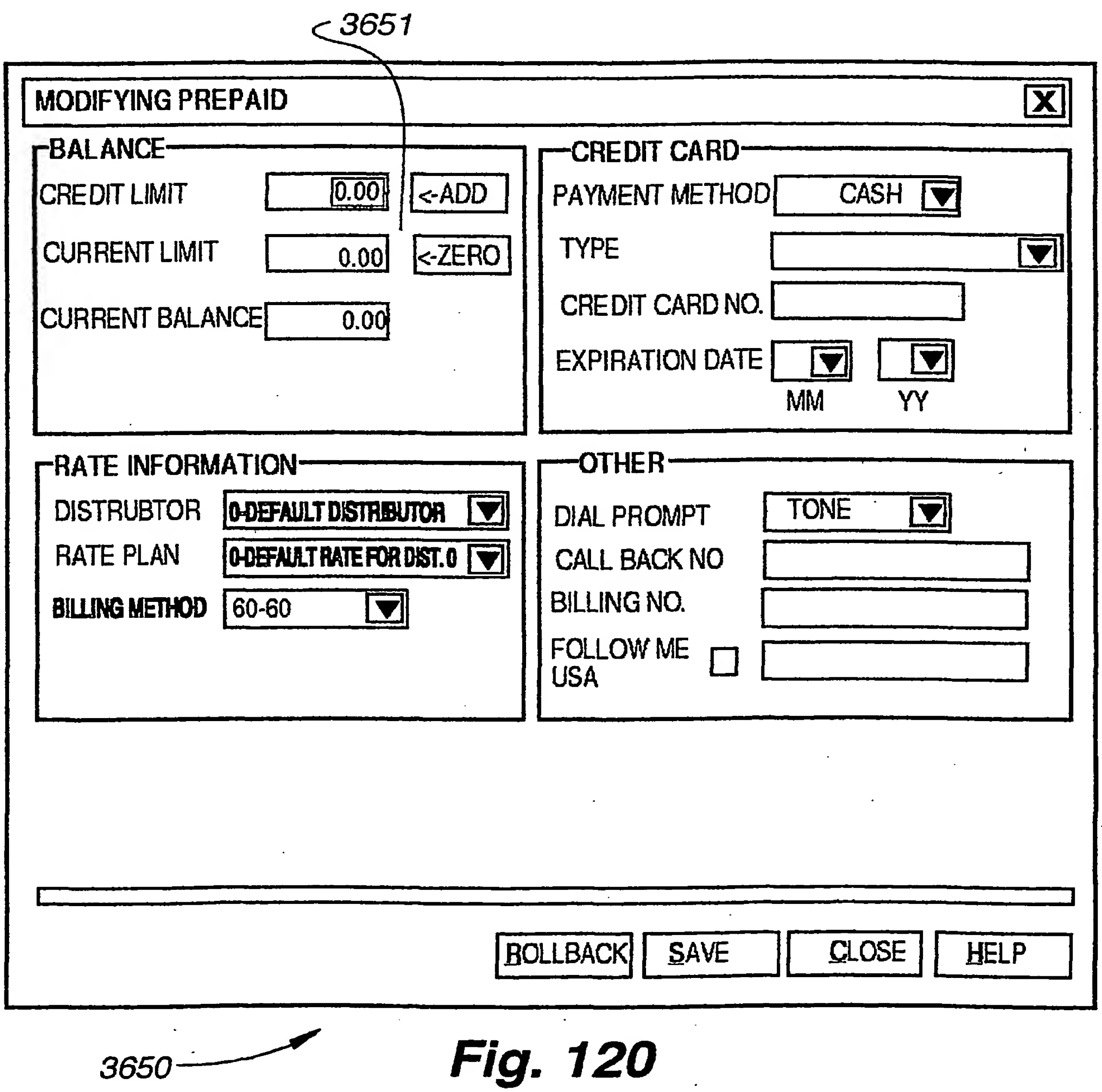


Fig. 120

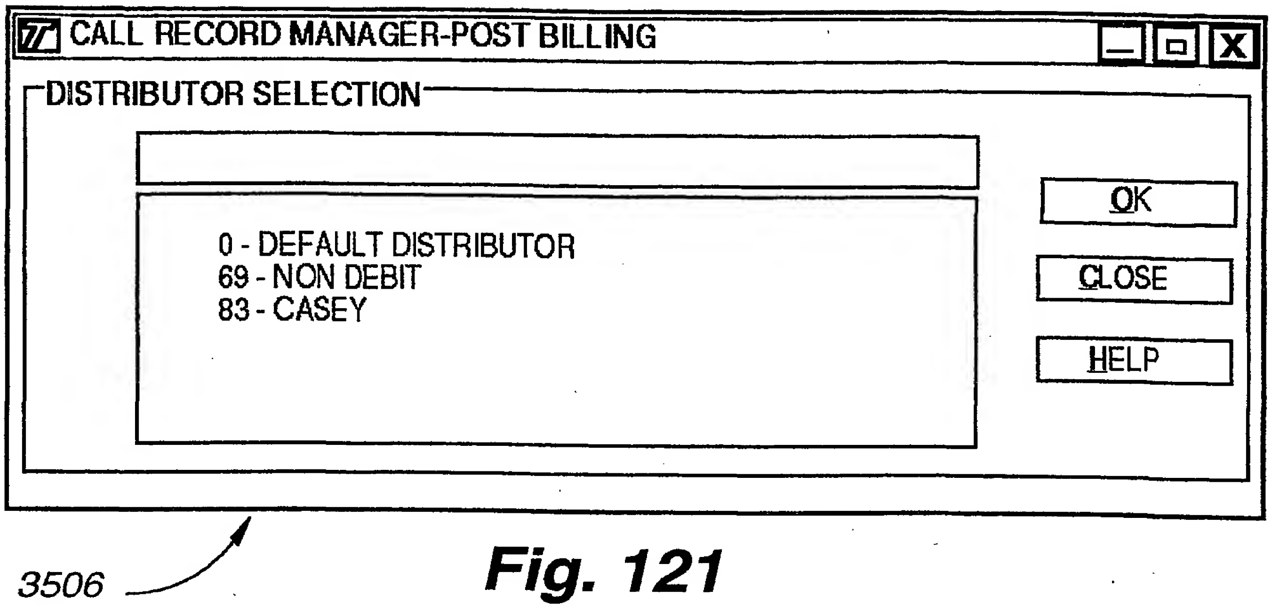


Fig. 121

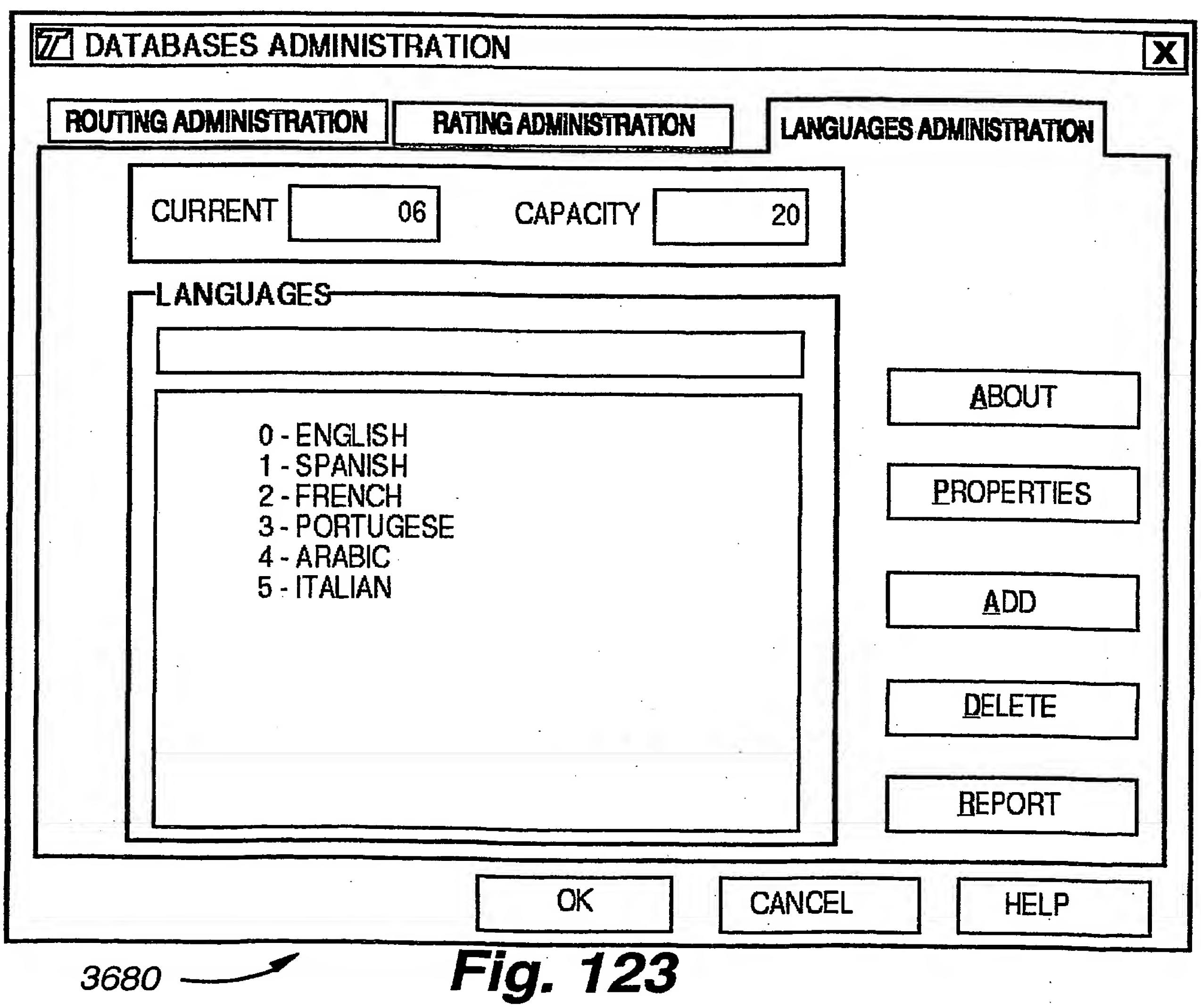
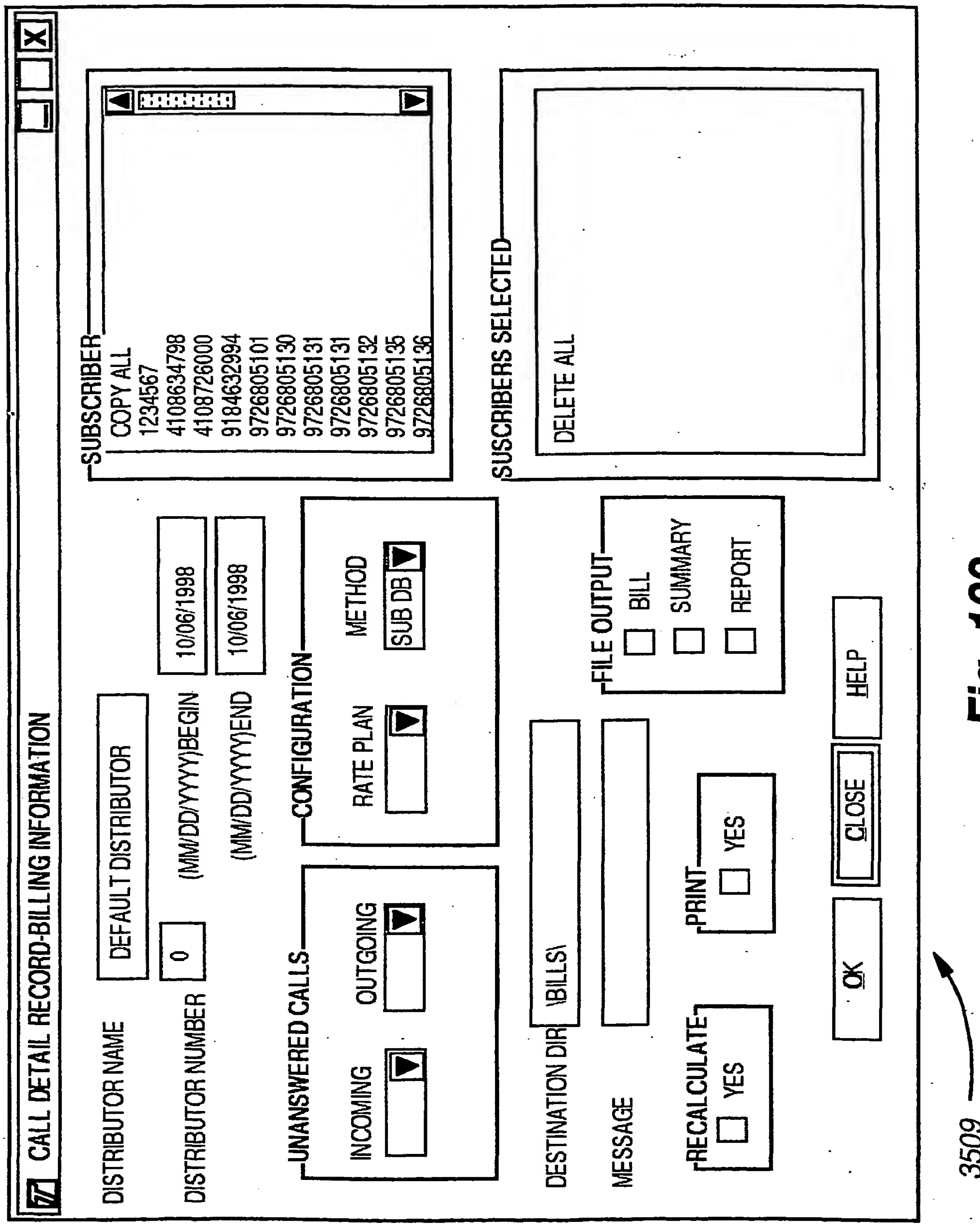


Fig. 123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OUTGOING
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MESSAGE
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BILL
SUMMARY
REPORT
RECALCULATE
YES
PRINT
YES
OK
CLOSE
HELP
3509

Fig. 122

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/02797

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :HO4B 7/204, 7/212, 7/216; HO4Q 7/20, 7/22, 7/24
US CL :370/319, 320, 321, 325, 335, 336, 342, 347,
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/319, 320, 321, 325, 335, 336, 342, 347,

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST:
search terms: MSC, CDMA, TDMA, FDMA, GSM, AMPS, home/visitor location register, scalable

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X, P	US 6,014,561 A (MOLNE) 11 January 2000, see fig. 2.	1-104
X, P	US 5,940,384 A (CARNEY et al) 17 August 1999, see fig 1.	1-104
A,P	US 6,016,426 A (BODELL) 18 January 2000, col. 12, lines 37-57.	1-104
X	US 5,592,480 A (CARNEY et al) 07 January 1997, col 6, lines 14-44.	1,6,12,13,18-20,27-35, 46-53,59,6 1-63,66-70

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
23 APRIL 2000	16 MAY 2000

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	ANDREW LEE For Eugenia Jones
Facsimile No. (703) 305-3230	Telephone No. (703) 305-3500

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/02797

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,845,211 A (ROACH, Jr.) 01 December 1998 see fig.1 & col 6, lines 14-44.	1-104
Y	US 5,729,536 A (DOSHI et al) 17 March 1998, see fig .1.	1-104
Y	US 5,519,760 A (BORKOWSKI et al) 21 May 1996, col 7, lines 36 +.	1-104

Form PCT/ISA/210 (continuation of second sheet) (July 1998) ★

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H04B 7/204, 7/212, 7/216, H04Q 7/20, 7/22, 7/24	A1	(11) International Publication Number: WO 00/46938 (43) International Publication Date: 10 August 2000 (10.08.00)

(21) International Application Number: PCT/US00/02797

(22) International Filing Date: 4 February 2000 (04.02.00)

(30) Priority Data:
09/245,292 5 February 1999 (05.02.99) US

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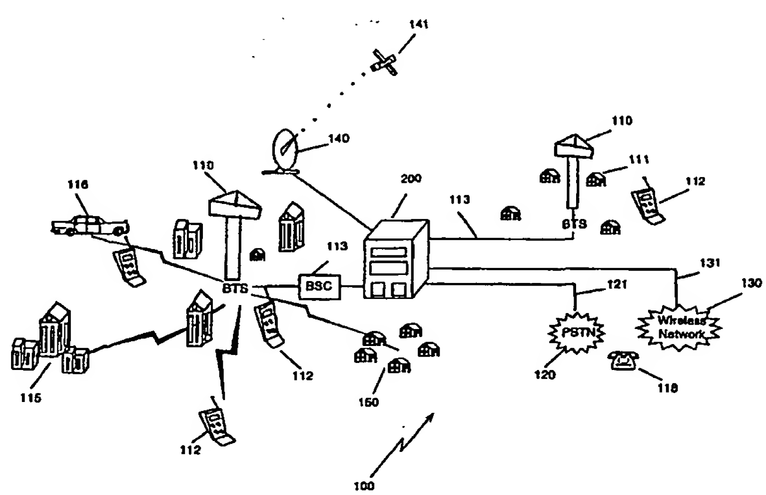
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: MULTI-PROTOCOL WIRELESS COMMUNICATION APPARATUS AND METHOD



(57) Abstract

A scalable, multi-protocol mobile switching center (200) in a wireless communications network provides communications control for digital and analog wireless communication devices (110, 112, 115, 116, 118, 140) including devices that operate according to GSM and IS-31 standards. The hardware and software architecture of the switching center is designed so that processing that is unique to a particular protocol is performed at the lowest possible level, and remaining processing can use generic procedures. The switching center incorporates a home location register and visitor location register that are used in conjunction with software applications to determine the protocol of mobile communications devices using the wireless communication network. The mobile switching center can be used to provide a large scale distributed wireless network or a small scale wireless network. The switching center can also be used as an adjunct to a private branch exchange to provide in-building wireless services and call control. Graphical user interfaces make the wireless communications network easy to maintain.

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EE	Estonia						

MULTI-PROTOCOL WIRELESS COMMUNICATION APPARATUS AND METHOD

Field Of The Invention

The invention is directed to a wireless communications apparatus and method. In particular, the invention is directed to a multi-protocol, scaleable wireless switching platform and method.

Background

Wireless communications in the United States were initially conducted solely through analog systems and protocols. The most prevalent analog protocol remains the Advanced Mobile Telephone System (AMPS) protocol. To handle wireless communications and to allow interconnection with traditional wired land-lines, switching systems and base stations were required. The analog switching systems are large and are designed to cover large markets and handle large volumes of calls.

In the 1990's digital systems and protocols began to be used for wireless communications. Examples of digital protocols are the Global System for Mobile Communication (GSM) code division multiple access (CDMA), and time division multiple access (TDMA). When wireless networks began to switch to digital protocols, they could not simply upgrade their analog base stations to digital. New equipment for the digital facilities was required. However, the networks continued to use large switching systems designed to cover their large spread markets. Examples of large switching systems are AT&T's 5ESS® system and the AXE system made by Ericsson. The 5ESS® switch is described in detail in the AT&T Technical Journal, Vol. 64, No. 6, part 2, July/August 1985, pages 1305-1564.

Large switching systems are designed to cover large markets and to handle many thousands of customers. The larger systems have the advantage of being able to provide a wide range of call options, such as call forwarding, caller identification and call waiting. The switching systems are expensive, however and, therefore, may not be appropriate for small markets and wireless providers. Additionally, large switching systems can be inefficient because of the added additional cost for increased back hauls of calls.

Typical switching systems employ proprietary architectures that use hardware components for switching, external interfaces, operating system, and control.

Summary Of The Invention

A multi-protocol mobile switching center (MSC) provides wireless communications for mobile devices operating on a local wireless network according to any standard protocol including those of the Global Systems for Mobile Communications (GSM) standards and IS-41 standards (including time division multiple access (TDMA), code division multiple access (CDMA), and Advanced Mobile Telephone System (AMPS)). The MSC may be incorporated onto a single platform having a home location register (HLR) and an authentication center (AC or AuC), as well as a visitor location register (VLR) and an equipment identity register (EIR).

The multi-protocol MSC is scalable so that it may be used for a small number of customers, such as in a rural setting to provide telephone access, or as part of an in-building communications network. The scalable, multi-protocol MSC may also be used to construct a large, distributed wireless network. Thus, the scalable, multi-protocol MSC provides the flexibility to be used with a wide range of customer bases, and within a variety of different typographies.

Because the MSC can process wired and wireless calls according to any protocol, a single switching center may serve customers who operate mobile and fixed communications devices, regardless of protocol. This true multi-protocol functionality makes this switching solution extremely efficient and cost effective, and eliminates the need for separate, protocol-specific components.

The multi-protocol MSC can be housed in a standard chassis. The multi-protocol MSC can use standard, off the shelf hardware for most data storage and processing functions. The multi-protocol MSC can be easily updated to take advantage of industry advances by simply replacing select components in the chassis.

The multi-protocol MSC provides full-featured telephone and data services, including wired and wireless analog and digital telephony, conference calling, prepaid

calling, emergency call routing and long-distance resale. The multi-protocol MSC also provides pocket switching applications such as asynchronous transfer mode (ATM).

The multi-protocol MSC incorporates advanced graphical user interfaces (GUIs) that display system data in a convenient, easy to access format. A system operator can quickly select data for display, and can easily modify selected data entries. The system operator can control operation of the multi-protocol MSC using the intuitively structured GUIs.

The multi-protocol MSC may incorporate a number of sophisticated features in addition to the HLR, VLR, EIR and the authentication center. These features include an operations and maintenance center, wire line and tandeming services, and hot (real-time) billing and prepaid services.

When used for distributed switching, the multi-protocol MSC may reduce build out and operational costs associated with large switching centers. This architecture also eliminates needless back hauling by switching local calls locally. Finally, the architecture allows for add on as a wireless customer base expands.

The multi-protocol MSC includes a first interface that receives digital and analog communication according to a first protocol and a second interface that receives digital communication according to a second protocol. The first and the second interfaces include inter system (system-to-system) message handlers and intra system (within system) message handlers.

The hardware and software architecture of the MSC is designed to use generic signaling as much as possible to provide call connection and other functions. Protocol-specific communications are handled at a device handler (lower) level, and higher level processing uses generic messaging. A table may be used to map messages of the different protocols to the generic messages used by the MSC. The hardware of the aircore system is based on off-the-shelf industry standard components for each of the four areas typically found as proprietary in current systems. The use of

off-the-shelf standardized switching components, interface boards, operating system and control processing provide a unique evolution path for the aircore system.

The HLR and VLR are structured so that data that does not depend on a specific protocol is stored in a common memory portion while protocol-specific data is stored in protocol specific portions of the HLR and VLR. This logical arrangement of the HLR and VLR provides for quick access to data by components of the MSC and allows for easier updating by a system operator.

An advanced intelligent message (AIM) handler interfaces with the VLR and the HLR to determine the current location and identification of mobile units homed on the HLR or roaming in the local wireless network. The AIM also determines the protocol applicable for the mobile unit. For calls received at the MSC from a local wireless network base station, the protocol determination may be made by reference to the protocol of the base station. For multi-protocol base stations, the determination includes decoding information provided in the service request or similar message sent by the base station. For other mobile units, the MSC may communicate with external wireless components such as other HLRs, VLRs, and MSCs.

The MSC includes an authentication and registration system that controls registration of mobile communications devices operating on the system controlled by the MSC. The authentication and registration system also provides encryption and ciphering of voice and data communications.

The MSC can also be used as an adjunct to a private branch exchange (PBX) to create an in-building wireless network. Used as such, the MSC and HLR can be used to route calls preferentially among mobile units and fixed telephones and other communications devices.

Brief Description Of The Drawings

The invention will be described in conjunction with the following figures, in which like numbers refer to like features, and wherein

Figures 1a - 1d show wireless communication environments according to the invention.

Figure 2 is a block diagram of an aircore switching platform.

Figure 3 shows a wireless loop architecture.

Figure 4 shows a fixed wireless loop architecture.

Figure 5 shows the aircore platform with local area mobility.

Figure 6 shows the aircore platform with system level mobility.

Figure 7 shows the aircore platform with full scale mobility.

Figure 8 shows a wireless network architecture.

Figure 9 is a block diagram of aircore functions.

Figures 10 is a block diagram of the aircore software architecture.

Figure 11 is a block diagram of the advanced intelligent message handler architecture.

Figure 12 is a block diagram of the A-interface message handler.

Figure 13 is a block diagram of the ISDN user part message handler.

Figure 14 is a block diagram of a intersystem message handler.

Figure 15 is a block diagram of a device handler for voice input-output devices.

Figure 16 is a block diagram of a device handler for digital interfaces.

Figure 17 is a block diagram of a device handler for ISDN interfaces.

Figure 18 is a block diagram of a device handler for signaling system 7 communication.

Figure 19 is a block diagram showing software interlayer communications.

Figure 20 is a logical representation of the home location register.

Figure 21 illustrates the HLR/VLR database structures.

Figure 22 is a block diagram illustrating the location management feature of the visitor location register.

Figure 23 is a state machine for mobile originated call processing.

Figure 24 is a state machine for PSTN originated call processing.

Figure 25 is a state machine for mobile terminated call processing.

Figure 26 is a diagram of a near end facility state machine.

Figures 27 is a diagram of a far end facility state machine.

Figure 28 is a diagram illustrating mobile unit hand off.

Figure 29a shows the software components used for call processing.

Figure 29b shows the object structure for the aircore call processing.

Figure 29c is a flow chart illustrating an authentication process.

Figures 30-34 are flow charts showing message signaling associated with interface maintenance.

Figures 35-40 are flow charts showing message signaling associated with trunk management.

Figures 41-47 are flow charts showing message signaling associated with mobility management.

Figures 48-66 are flow charts showing message signaling for call processing.

Figures 67-71 are flow charts showing message signaling associated with call processing with an external HLR.

Figures 72 is a flow chart showing message signaling associated with hand off pre-processing.

Figure 73 is a logical diagram of a prepaid rating system.

Figure 74 is a flow diagram illustrating emergency call processing.

Figure 75 is a block diagram illustrating first party call control.

Figure 76 is a block diagram illustrating third party call control.

Figures 77-79 are block diagrams of call delivery methods using third party call control.

Figure 80 is a block diagram of an in-building wireless communications network.

Figures 81-84 are block diagrams of an embodiment of the aircore platform hardware architecture.

Figures 85-86 are block diagrams of another embodiment of the aircore platform hardware architecture.

Figures 87-123 illustrate graphic user interface screens for use with the aircore platform.

Detailed Description Of The Invention

Mobile telecommunications (radio) systems that permit customer calling from mobile stations such as automobiles, or small light weight hand held personal communications units are becoming increasingly prevalent. These systems use the principles of cellular technology to allow the same frequencies of a common allocating radio bandwidth to be reused in separated local areas or cells of a broader region. Each cell is served by a base transceiver station comprising a group of local transceivers connected to a common antenna. Base station systems, each including a controller and one or more transceiver stations, are interconnected via a switching system, called a mobile switching center (MSC), which is also connected to the public switched telephone network (PSTN), and the Public Land Mobile Telephone Network (PLMN). These mobile telecommunications systems are now entering a second generation characterized by digital radio communications with a different set of standards, such as the European Global System for Mobile Communications (GSM) standard promulgated by the Special Mobile Group (SMG). The GSM standard is also being adapted for use in the United States. In addition, in the United States, CDMA, TDMA, DAMPS, and AMPS are used for digital cellular mobile communications.

The mobile telecommunications systems have many components that need to communicate signaling information for controlling the establishment of connections. Such signaling information is communicated over channels that are separated from the channels carrying actual voice or data communications between the connected customers. Among the components that need to communicate to establish voice and data communication links are the mobile units, the base station system connected by radio to the mobile units, the mobile switching center and the various databases that are consulted for the establishment of mobile calls. These databases include a home

location register (HLR) with an authentication center (AC (IS-41) or AuC (GSM)), a visitor location register (VLR), and an equipment identification register (EIR).

Signaling messages among these components are processed by many expensive protocol handlers. In the past, these protocol handlers were too expensive to permit incorporation into a single unit. Modern switching systems typically include expensive MSCs, such as AT&T's 5ESS® switch. These systems only make sense for deployment when there are a large group of mobile customers who will use the system.

This invention uses advanced signal processing, a novel method of structuring signal processing software and an enhanced home location register/visitor location register to provide multi-protocol, scaleable mobile telecommunications capability. The software architecture is specifically designed so that generic processing is used to the maximum extent possible to process signals and data related to different digital and analog protocols including GSM, TDMA, CDMA and AMPS, and proprietary protocols.

Figure 1a shows a general arrangement of a mobile telecommunications environment 100. At the heart of this environment 100 is an aircore platform 200 of the invention. The aircore platform 200 receives messages from, and transmits messages to a variety of fixed and mobile sources, conforming to each of the protocols employed by the sources.

Base transceiver stations (BTSs) 110 receive messages from and transmit messages to the aircore platform 200 over land lines 113. The land lines 113 may be any telecommunications medium that is capable of high speed data transmission, such as fiber optic cable, T-1 and E-1 lines and coaxial cable, for example.

The BTS 110 transmits messages to and receive messages from mobile and fixed sources. In Figure 1a, the BTSs 110 are shown in wireless communication with mobile phones 112, a mobile phone in a car 116 (a roaming mobile phone), a microcell 115, and a wireless local loop 150. The wireless local loop 150 may include

several connections. The wireless local loop 150 is described in more detail below. A telephone 118 may operate in conjunction with a private branch exchange (PBX).

The BTSs 110 may operate in conjunction with the fixed and mobile sources, according to one of several wireless protocols as set forth above.

The aircore platform 200 communicates with a public switched telephone network (PSTN) 120 via a wired path 121 and with a wireless network 130 via a signal path 131.

The aircore platform 200 also communicates with a satellite 141 via a satellite receiver 140.

Figure 1b shows a GSM wireless environment 101. The aircore platform 200 connects to the BTS 110 via a base station controller (BSC) 105. Mobile units 112, the roaming mobile phone 116, the wireless local loop 150 and the microcell 115 communicate by way of wireless radio channels with the BTS 110. The aircore platform 200 also connects to a GSM MAP network 133 via landline 132 and to the PSTN 120 via the landline 121. Finally, the aircore platform 200 communicates with the satellite 141 via the antenna 140.

Figures 1c and 1d show wireless environments 102 and 103, respectively. The wireless environment 102 is used with CDMA-protocol mobile units and base stations, and the wireless environment 103 is used with TDMA-protocol wireless units and base stations.

Figure 2 shows the aircore platform 200 in more detail. In Figure 2, the aircore platform 200 includes a mobile switching center (MSC) 210. The MSC 210 is configured such that the aircore platform 200 can receive and transmit multiprotocol wireless communications and wired communications with a variety of platforms. The MSC 210 may include a visitor location register (VLR). Alternately, the VLR may be separated from the MSC 210. The aircore platform 200 also includes a home location register (HLR) 212. The HLR 212 includes permanent information about customers who use the local environment serviced by the aircore platform 200. The data stored in the HLR 212 is the permanent data that is independent of the customer's

present location, plus temporary data stored such as the address of the system (may be signaling system 7 (SS-7) or other system) where the mobile unit is currently registered and the address of service centers that have short messages for a mobile unit. An example of such a short message is a request to turn on a voice message waiting lamp indicating that a voice message has been stored for the mobile unit's use in a voice messaging system. These addresses are erased after the short messages have been delivered. The signaling system 7 (SS-7) is described in detail in A.R. Modarressi, et al., "Signaling System No. 7: A Tutorial," *IEEE Communications Magazine*, July 1990, pp. 19-35.

The VLR contains the profile data for the mobile unit and the transient data for each mobile customer, including the mobile unit's present or most recently known location area, the mobile unit's on/off status, and security parameters.

An authentication center 213 is used to ensure that only properly authorized mobile and wired sources communicate through the aircore platform 200. The authentication center 213 provides authentication encryption parameters to ensure that a mobile customer cannot falsely assume the identity of another mobile customer and provides data for encryption of the voice data, and control signals transmitted via the air between the mobile unit and the servicing base station system. Encryption is desirable for the transmission of messages between the mobile unit and the radio transceiver at a base station serving that mobile unit because it is possible to listen in, or tap, the radio channels carrying voice communications.

An equipment identity register (EIR) 211 includes a database of the mobile equipment using the aircore platform 200, including specific protocols and equipment preferences. The EIR 211 retains the ranges of certified equipment identifications and the ranges of, or the individual equipment identifications that are under observation or barred from service. The equipment identification information is received from a mobile unit at the MSC 210. The EIR 211 is used to verify that the equipment number of the mobile unit is certified for use in the public network and is not on the observation or service barred list.

The MSC 210 is connected to other wireless network components and to the PSTN for accessing land-based customer stations and to the integrated services digital network (ISDN) for communicating according to ISDN protocols. A base station system (BSS) 104 may include the BSC 105 and one or more BTSs 110 for communicating with mobile units. The BSS 104 and the mobile units communicate via radio connections. The BSS 104 is also connected via trunks to carry the voice, data, and control messages between the mobile units and the MSC 210. The BSC 105 and the BTS 110 may be in different physical locations (for example, the BSC 105 may be co-located with the MSC 210 in which case a trunk is required to interconnect the two). This is done since the communications between the BTS 110 and the BSC 105 can typically be compressed to optimize the BTS connectivity requirements.

Figures 3 - 7 show different mobility architectures that can be used with the aircore platform 200. In Figure 3, the aircore platform 200 is shown communicating with the BTS 110. The BTS 110 may service the wireless local loop 150. The aircore platform 200 may also connect with the PSTN 120.

Figure 4 shows the aircore platform 200 used in conjunction with fixed wireless local loop customers. In Figure 4, the fixed wireless local loops 151 include a number of fixed customers in each of the local loops 151. The local loops 151 provide telephony services to fixed wireless customers in their respective loops. The services are provided via a fixed terminal (not shown) that is attached to a location and typically extends via a standard two-wire or similar connection to an analog telephone within the location. Call processing and feature management are handled by the aircore platform 200 as for a normal wireless customer. The only difference for the aircore platform 200 is that the area of operation for the fixed terminal does not change. Even though the terminal is using a wireless interface for communications, the terminal's location remains fixed. The aircore platform 200 processes the calls to and from the customer in the same manner as with mobile wireless calls because the air interface determines the protocol and the feature set that is to be used to communicate with the customer's fixed terminal. The protocol can be any of the

wireless protocols (CDMA, TDMA, AMPS, GSM). To limit the area of communications for a particular fixed terminal, the aircore platform 200 can be configured to only allow service to a particular location area for a particular fixed terminal.

The aircore platform 200 provides a full range of mobile services to a wireless local loop, or location area. In Figure 5, the aircore platform 200 is shown providing mobile services to a wireless local loop 152 and a wireless local loop 153. In this type of mobility situation, customers may move with their wireless terminals in a given wireless local loop or location area. Movement outside of the location area is not supported for these types of terminals. A typical implementation of this type of mobility is provided in a village or town scenario where the coverage is disjointed from other parts of the telecommunications system.

Figure 6 shows a system level mobility scenario that permits mobility for the customer across all location areas under the control of the local aircore platform 200. In Figure 6, the location area 154 and the location area 155 are both serviced by the aircore platform 200. Moreover, customers in the location area 154 may freely move through the location area 154 and the location area 155 and maintain wireless communications with the aircore platform 200. This type of scenario can be found in multiple towns or villages where a common aircore platform 200 is shared and the coverage is contiguous or there is a considerable amount of allowable travel between the locations covered by the system.

Figure 7 shows a full scale mobility scenario. In Figure 7, the aircore platform 200 communicates with a public land mobile network (PLMN) 158 and with local wireless loops 156 and 157. The local wireless loops 156 and 157 also communicate with the PLMN 158. This configuration provides for incoming and outgoing roaming traffic to and from the local aircore platform 200 to other switching centers, which may also be aircore platforms 200.

Figure 8 is a block diagram of a wireless network architecture according to the invention. In Figure 8, the aircore platform 200 includes a MSC/VLR 210', a home

location register 224, an authentication center 226, and an equipment identification register 225. The aircore platform 200 communicates with the base station system (BSS) 104' using one or more protocols including GSM, CDMA, TDMA, and AMPS. The aircore platform 200 also communicates with the PSTN 220 and other elements of the wireless network. An alternate mobile telecommunications switch is also shown in Figure 8. A MSC/VLR 210'' is coupled to the PSTN 220 and the BSS 104". However, other modular components used in the mobile telecommunications environment are located remotely from the MSC/VLR 210''. A system management controller 230, a home location register 221, an equipment identification register 222 and an authentication center 223 may be physically separated from the MSC/VLR 210''. However, the functions of these modular components remain the same, whether they are located with or remote from the MSC/VLR 210' and 210'', respectively.

Figure 9 shows the functions and connections of the aircore platform 200. In Figure 9, the visitor location register, the home location register, the equipment identification register and the authentication center are shown co-located with the MSC 210. The aircore platform 200 connects to the PSTN 120 via a T-1/E-1 line. The aircore platform 200 is adapted to receive land-line originated telephone messages. The aircore platform 200 can then send a connect message to an appropriate base station system. The aircore platform 200 also allows intersystem connection to an IS-41 wireless network 170 via a SS-7 link and a GSM wireless network 160 via a SS-7 link. Optionally, these links may be based on other communication carriage mechanisms such as IP, X.25, frame relay, or asynchronous transfer mode (ATM).

The aircore platform 200 provides for intrasystem, or base station, wireless communication using GSM protocols via a GSM BSC 240 and BTS 241. The aircore platform 200 provides wireless communications using CDMA and TDMA via a IS-634 link, an IS-95A BSC 244, a BTS 243 and a IS-136 BSC 242 and BTS 249. The aircore platform 200 communicates with an AMPS BTS 246 using the ISDN PRI+ or

the IS-634 protocol. The aircore platform 200 provides communications with a private branch exchange (PBX) 248 via T-1/E-1 lines. The aircore platform 200 also provides for connection to a billing system 260 using TCP/IP protocols, for example, and for voice mail and messaging functions via voicemail module 250.

TABLE A

TYPE	PROTOCOL	APPLICATION
Base Station	GSM "A" (Series 4 and 8)	GSM Network
	IS-651 & J-STD	US GSM based PCS
	IS-634 (IS-136)	DAMPS Network
	IS-634 (IS-95A)	CDMA Network
	IS-634 (AMPS)	Analog Network
	ISDN PRI+(AMPS)	Analog Network
Intersystem	GMS 09.02	GSM Network
	IS-652	US GSM based PCS
	ANSI-41	DAMPS, DCMA, AMPS Network
PSTN	T-1	T-1 Interface (various protocols) to the PSTN
	E-1	E-1 Interface (various protocols to the PSTN
Tandem	T-1	T-1 Interface tandem call traffic between local PBX and the PSTN
	E-1	E-1 Interface tandem call traffic between local PBX and the PSTN
Voice Mail	T-1	T-1 Interface to voice mail system
	E-1	E-1 Interface to voice mail system
Billing Center	TCP/IP	Interface for the transfer of Call Detail Records
NMC/OMC	TCP/IP	Interface for the exchange of Network Management related information

Table A shows a list of interfaces from the aircore platform 200 and the functionality each of the interfaces adds. A Network Management Center/Operations and Maintenance Center (NMC/OMC) 262 communicates with the aircore platform

200 using TCP/IP protocols, for example. The billing system 260 and the NMC/OMC 262 may also communicate with the aircore platform 200 using CCITT X.25 protocols.

Figure 10 is a block diagram of the aircore software architecture 300. In Figure 10, the architecture 300 is shown including a system control module SCM layer 310, a call processing control module handling the real time application layer 400, and a device handler layer 500. The SCM layer 310 maintains responsibility for non-real time related applications, such as report management and configuration. The SCM layer 310 generates and collects various types of report data, system configuration information and system maintenance procedures. The SCM layer 310 may be logically and physically separated from the rest of the aircore software architecture 300.

The call processing control module of the real time application layer 400 handles the application layer tasks that are real-time related. At the real time application layer 400 of software, direct knowledge of specific protocols is not required. Instead, this layer handles functions from a generic standpoint. For example, a call processing state machine processes mobile originated call set up in the same manner regardless of the type of interface used to connect to the base station equipment. The event set and state machine commonality allow lower layers of software to change without effecting the call processing control module of the real time application layer 400.

The device handler layer 500 is the lowest layer of software in the aircore software architecture 300. The device handler layer 500 contains the specific software applications to receive and transmit protocol specific messages.

The SCM layer 310 includes a control panel (CTL) 312, which is the father process of all the other processes in the system. The CTL 312 is responsible for startup and auditing of the overall aircore software architecture 300. Once started, the CTL 312 is only involved in limited auditing functions.

A call record management (SCR) 314 tracks the call report data generated in the system. These records can be used for billing tracking, system tendencies, or prepaid type of access. Call records are archived and the files rotated periodically. For example, the files may be rotated hourly. Real-time output is accessible via standard output options such as a printer or a screen output. Archived output is accessible on screen, or may be accessed over a standard TCP/IP network or dial up.

An operational measurements manager (OMM) 316 is responsible for tracking system counters. A count is defined as the occurrence of a particular situation. Each time the situation occurs, the counter is incremented. Operational measurements are archived and the files rotated periodically. For example, the files may be rotated hourly. Each time a new file is created, each of the counters is reset to zero. This type of data is captured to allow an operator to track system performance and tendencies over time. Operational measurements are archived into files rotated periodically. Real-time output is accessible using standard output options such as a printer or a screen output. Archived output is accessible on-screen or can be accessed over a standard TCP/IP network or dial up.

A real-time log report manager (RTL) 318 tracks system level reports. System level reports are generated to notify an operator of certain tasks or situations occurring on the aircore platform 200. For example, at the top of the hour, the system level audit log reports may be output. Log reports range from reporting normal system maintenance events to system status changes. Log reports are archived into files rotated periodically. Real-time output is accessible using standard output options such as a printer or a screen output. Archived output is accessible on screen or can be accessed over a standard TCP/IP network or dial up.

An auto removal process (AUTO) 322 is responsible for automatic removal of outdated archived report files. Automatic removal may occur on a periodic basis, such as monthly.

A network management database administration (NMS) 324 allows access to databases that provide configuration information for routing, rating and language for

mobile devices. A system configuration (SYSCFG) 326 allows access to the configuration of system telephony hardware resources. A system maintenance (SYSMTC) 328 allows access to operator-initiated maintenance procedures.

A visitor location register interface VLI 332 provides the operator access to a visitor location register. A home location register interface (HLI) 334 provides an operator interface to the home location register and authentication center information. An equipment identity register interface (EII) 336 provides an operator interface to the equipment identity register. The VLI 332, HLI 334 and EII 336 may be implemented as a graphical user interface(s) (GUI) or as batch type operations. These interfaces will be described in more detail later.

The call processing control module (CPCM) of the real time application layer 400 includes a recovery and startup (REC) 402, which is the father process of the software subsystems in the real time application layer 400 and at the device handler layer 500. The REC 402 manages the maintenance states for the trunk and signaling facilities in the real time application layer 400. The REC 402 interfaces with each of the device handlers in the device handler layer 500 for maintenance and status as well as with graphical user interface-based applications in the SCM layer 310 to process operator initiated maintenance requests. The REC 402 also initiates an audit of all real time application layer 400 subsystems. The audit may run every two minutes, for example, and provides assurance that all subsystems are running properly.

A fault analysis unit (FAU) 404 is responsible for the collection of all log reports and operational measurement related data created within the CPCM 400. The FAU 404 to real-time layer interface is a singular path for this information to pass. All CPCM 400 subsystems have access to pass events to the FAU 404 for this purpose.

The timer manager (TIM) 406 provides timing facilities to call processing control module subsystems in the aircore platform 200. The TIM 406 is used for application level timers that operate on a one second or greater granularity. Timers are stored in a list and are tracked until they are released or until they expire. Timers

requiring finer granularity or those that are specific to a particular subsystem's requirements are controlled locally either in the subsystem or on board in the hardware. The timers associated with the aircore platform 200 will be described later in more detail.

A resource manager (RCM) 408 is used to manage base station resources connected to the aircore platform 200. The RCM 408 has the capability to configure, download, and track the state of individual cell site components as well as the base station as a whole.

A CPCM call record management (CCR) 412 module provides for local collection of call detail record (CDR) information for calls in progress. When calls are completed, the CDR information is transferred from the CCR 412 to the SCR 314 in the SCM 310, where the call record data is processed and stored.

A call processing manager (CPM) 414 provides the processing required for all communication channel establishment, tear down, feature processing and hand off control. The state machines in place in the CPM 414 are based on a half-call model. Each party in a session moves through a defined set of states based on received and sent events, and timers used. Each side of a call steps through its own state. The two sides of the call progress together. For a basic call setup, the state of one side of the call is never more than one step ahead or behind the state of the other side. In the CPM 414, each call placed requires the creation of a session object. This object is created based on an index number created from the board span and channel used by the originator of the call. The session adds and removes call objects as dictated by the progress of the call. The reference number for the session is always based on the originator's board span and channel. However, the session may also be indexed via the index number of the board, span and channel of any of the involved parties.

A hand off processor (HOP) 416 is responsible for the preprocessing required for hand off or hand over (GSM). Based on the technology and the involvement of intersystem border cells, the level of involvement of the HOP 416 varies from one air interface protocol to the next. However, like other modules performing specific

functions, the unique aspects of the protocol are handled internally in the HOP 416. The interface to the CPM 414 for hand off processing is made generic. Preprocessing in relation to handoff processing refers to the collection of data and the decision process used to determine the appropriate base station to target for the hand off. This entire process has been formed into a generic procedure within the aircore software architecture 300.

A tone and announcement manager (TAM) 418 is responsible for management of the digital signal processor resources in the system used for playing tones and announcements. The TAM 418 interacts directly with the CPM 414 to provide the necessary digital signal processor allocations. The digital signal processors are controlled by components of the device handler 500. Direct communication to the device handler from the CPM 414 is avoided so that the CPM 414 does not have to maintain direct knowledge of the current digital signal processor configuration and allocations.

A visitor location register (VLR) 422 is responsible for establishing and maintaining a VLR database for the aircore platform 200. As shown in Figure 10, the VLR 422 is co-located with the aircore platform 200. However, the VLR 422 could be located remotely from the aircore platform 200. The VLR 422 is a collection of customer profiles for users currently active on the system. The VLR 422 is a dynamic database created and maintained while the aircore platform 200 is running. The VLR 422 communicates with threads inside an Advanced Intelligent Message Handler (AIM) 430, which will be described later, for real-time application messaging. Any communications to or from the VLR 422 from the CPCM 400 are received via the AIM 430. Communications with the VLI 332 are limited to those necessary to allow for the display of individual customer profile information, listing the current profiles in the VLR 422 and allowing an operator the ability to update customer profiles from the VLR database.

A home location register/authentication center (HLR) 424 is responsible for establishing and maintaining the HLR database for the aircore platform 200. As

shown in Figure 10, the HLR 424 is co-located with the aircore platform 200. However, the HLR 424 could also be located remotely from the aircore platform 200. In addition, the functions of the HLR 424 could be carried out in separate HLR and AC modules. The HLR 424 includes a collection of permanent customer profiles for users homed on the system. The HLR 424 is a static database that tracks the current location of a customer in addition to the individual profile parameters and status of customer-related features. The HLR 424 communicates with the AIM 430 for real-time application messaging. Any communications to or from the HLR 424 in the CPCM 400 are received via the AIM 430. Communications with the HLI 334 are limited to those necessary to allow for the manipulation of individual customer profiles, listing the current customer profiles in the HLR 424, and allowing an operator to update the customer profiles.

The HLR 424 also contains the functionality to perform the advanced security calculations used in digital air interface protocols. These calculations are based on a piece of secret data combined with a random number to yield a result that only has meaning to the authentication center and the mobile unit. This functionality is included in the HLR database and is integrated as part of the customer profile. The actual comparison of data is done in the AIM 430 or in the HLR 424 itself, depending on the protocol. Since the authentication center is integrated in the HLR 424, communications with the authentication center all funnel through the HLR 424. The authentication process will be explained in more detail later.

An equipment identity register (EIR) 426 is responsible for establishing and maintaining an EIR database for the aircore platform 200. The EIR database is a collection of the serial number information for mobile telephone handsets and other equipment in the system. The EIR 426 normally maintains at least three lists:

White - range listing of valid international mobile equipment identities (International Mobile Equipment Identity (IMEI)) (serial numbers).

Gray - list of individual serial numbers of questionable phones. Usage is operator dependent.

Black - list of individual serial numbers of equipment prohibited from using the system.

The EIR 426 is used with GSM-type systems. However, application to other system protocols may also be accomplished. The EIR 426 communicates with the AIM 430 for real-time application messaging. Any communications to or in the EIR 426 from the CPCM 400 are received via the AIM 430. Communications between the EIR 426 and the EII 336 are limited to those necessary to allow for the manipulation of list information. This includes allowing an operator to add, modify and delete from the information the EIR database.

The device handler 500 includes a portion of the AIM 430. The device handler 500 includes a device handler for digital CAS interface (DHD) 501, a device handler for voice input and output devices (DHA) 502, a device handler for ISDN interfaces (DHI) 503, a device handler for conference (DHC) 504, and a device handler for timers (DHT) 505. The AIM 430 also includes a device handler for SS-7 (DH-7) 510.

Figure 11 is a logical diagram of the advanced intelligent message handler (AIM) 430. The AIM 430 provides for advanced protocol processing, message routing and system interfaces for the wireless network. The AIM 430 is built around the steps required to establish call processing, mobility, and servicing in a wireless environment. The basic approach of the AIM 430 is to use a multi-thread system to isolate protocols and functions required for the mobility environment. Each different protocol family supported by the aircore platform 200 is handled by a thread specifically constructed for the message sent and state machine for that protocol.

Communications to various software entities such as the VLR, HLR, and EIR funnel through the AIM 430 subsystem. This approach is taken to remove the knowledge of the low layer message destination from each of those entities. This approach also allows for the isolation of protocol specifics to the AIM 430 layer of software. Finally, this approach allows for the seamless separation of these functions to physically separate entities without effecting the application software. The

following is an example of the benefit of this approach: When the CPM 414 needs to request the current location of a subscriber from the HLR 424, the message is sent to the AIM 430 subsystem without the direct knowledge of the HLR location or the protocol used to communicate with the HLR 424. The AIM 430 handles the routing (either internal or external) and the selection and construction of the appropriate message based on the protocol.

In Figure 11, a main AIM thread 438 is shown along with subordinate threads 431-436. In addition, a common memory 439 is used to share data related to a transaction or connection between the subordinate threads 431-436 and the device handler for SS-7 (DH-7) 510. Since each of the procedures followed for call establishment, location updating, etc., involve multiple threads and actions, the common memory 439 optimizes the performance of the AIM 430 by reducing the copying of data between threads while at the same time allowing data sharing across all of the threads by simply passing a pointer.

The A-interface message handler (AMH) 431 provides message decoding and encoding for interface processing between an external base station and the aircore platform 200 event structures and state machines.

Figure 12 is a block diagram of the logical architecture of the A-interface message handler AMH 431. Communications received from a base station interface are first interpreted by the AMH 431. The encoding and decoding specification for a particular protocol are contained in dynamic linked libraries 441 and 442 that are linked to the AMH 431. Each variant of the A-interface has its own unique set of builder/decoder dynamic linked libraries. Each type of A-interface utilizes its own instance of the AMH 431. Also shown in Figure 12 are timers 443_i through 443_n. The timers 443_i-443_n, which control operations of state machine call processing for a given connection, will be described in more detail later.

Figure 13 is a logical block diagram of the ISUP message handler (SMH) 436 logical architecture. The SMH 436 provides appropriate message conversion between the application programming interface and the internal aircore subsystem event

structures. As shown in Figure 13, the SMH 436 is logically linked to the board levels at boards 444_1-444_n.

Figure 14 is a logical block diagram of the intersystem message handler (IMH) 432 architecture. The IMH 432 encodes and decodes protocol messages related to a mobile unit from an external communications system. These messages are called Mobile Application Part. The encoding and decoding specifications for a particular protocol are contained in the dynamic linked libraries 445 and 446 that are linked to the IMH 432. Each variant of the MAP interface has its own unique set of builder/decoder dynamic linked libraries. Each type of MAP interface utilizes its own instance of the IMH thread 432. Also shown linked to the IMH thread are timers 447_1-447_n. The function of the timers 447 will be described in more detail later.

An authentication and registration processing (ARS) thread 434 (see Figure 11) provides appropriate calculations, comparisons and invocations of the required authentication for a given base station interface. A paging processing (PAG) thread 435 (see Figure 11) provides the processing necessary for paging in the AirCore system. Paging is the mechanism for locating and starting the process of notifying a mobile unit of an incoming call or message.

Figure 15 is a logical block diagram of the device handler for voice I/O devices (DHA) 502. The DHA 502 provides control of voice I/O resources in the aircore platform 200 that are used for playing tones and announcements. The DHA 502 is a single process that spawns individual threads for each digital signal processor that is accessible. As shown in Figure 15, the DHA 502 spawns digital signal processor threads 522_1 through 522_n. The aircore platform 200 uses the first five digital signal processors in the system to play standard tones. These tones are accessible to all ports on the system. This approach satisfies the requirements of playing ring-back or busy tones to all ports simultaneously. After the first five digital signal processors, the remaining digital signal processors are allocated to a pool that may be used in real-time call processing to play tones or announcements for call progressing. The five digital signal processors are used for the standard tones of ring

back, busy, fast busy, dial tone and confirmation beep. To play announcements for call progressing, the DHA 502 works with the tone and announcement manager (TAM) 418 (not shown, see Figure 10), which receives its commands from the CPM 414.

Figure 16 shows the device handler for digital channel associated signaling (CAS) interface (DHD) 501 in more detail. Channel associated signaling is a method of signaling in telecommunications where a portion of each channel between two entities is allocated for the carriage of the signaling and supervision in formations. The DHD 501 is a multi-thread, multi-process subsystem that provides for CAS processing.

Each channel in the DHD 501 is allocated a thread for processing the low layer protocol state machine. As shown in Figure 16, spans 511_1-511_n are associated with processing threads 512_1-$512_{24/32}$ and 513_1-$513_{24/32}$. The top layer process in the DHD 501 architecture is responsible for the interworking between the thread output in the real time application layer 400.

Figure 17 shows the device handler for ISDN interfaces (DHI) 503. The DHI 503 is a multi-threaded, single process subsystem that provides processing for common channel signaling interfaces. The DHI 503 is used internally in the aircore platform 200 to handle facilities (T-1 or E-1) that use common channel signaling methods. Common channel signaling provides a single signaling channel for the control of signaling and supervision information for many channels of resources (e.g., a single channel is used to pass the appropriate signaling for all of the associated traffic channels). Typically the signaling channel is based on an industry signaling method such as SS-7, LAPD, or TCP/IP. In the DHI 503, a top layer process is responsible for communications to the internal aircore platform 200 subsystems. Linked to the DHI 503 are board level threads 520_1-520_n. The board level threads 520_1-520_n are used to handle individual boards in the aircore platform 200.

Figure 18 is a logical block diagram of a device handler for SS-7 (DH-7) 510. The DH-7 510 exists for the purpose of handling the board level API for the SS-7

links in the system. The main tasks of the DH-7 510 are the basic assignment of threads to the SS-7 links and assuring proper message routing for inbound messages to the internal aircore subsystems and threads. Each SS-7 link established in the system has its own link level thread that exists as a subordinate thread to the main DH-7 510 thread.

Figure 19 is a logical block diagram showing interlayer communications among the SCM layer 310, the real time application layer 400 and the device handler layer 500. In Figure 19, a two-way communications path 350 between the CTL 312 and the REC 402 is used to start the real time application layer 400 and report the appropriate status information. One-way path 351 is used to transfer CDRs from the real time application layer 400 to the SCM layer 310. One-way path 352 between the FAU 404 and the RTL 318 is used to transfer report and operational measurement pegs from the real time application layer 400 to the SCM layer 310. One-way path 353 between the SYSMTC 328 and the REC 402 is used to pass maintenance related commands to the real time application layer 400 from the SCM layer 310. Two-way path 354 from the VLI 332 to the VLR 422 is used to exchange information between the VLR 422 and the VLR graphical user interface 332. Two-way path 355 between the HLI 334 and the HLR 424 is used to exchange information between the HLR 424 and the HLR graphical user interface 334. Two-way path 356 between the EII 336 and the EIR 426 is used to exchange information between the EIR 426 and the EIR graphical user interface 336.

Path 450 between the REC 402 and subsystem at the device handler layer 500 is defined for startup, status and maintenance communications used to interact with the telephony board level hardware. The REC 402 communicates directly with all device handler level subsystems with the exception of the DH-7 510, which is handled via communications with the AIM 430. Two-way path 451 between the CPM 414 and the device handler layer 500 is established for the exchange of messages for call processing related activities in the aircore platform 200. The CPM 410 communicates directly with all device handler 500 level subsystems with the exception of the DHA

502 and the DH-7 510. Communications path 452 between the TAM 418 and the DHA 502 provides for the allocation and deallocation of voice I/O resources for tones and announcements. Much like trunk groups that abstract the physical location of trunks, this level of communication abstracts the physical location of the digital signal processors used for playing the tones and announcements. Communications path 453 between the AMH 431, SMH 436, IMH 432 and the DH-7 510 provides for communications between the SS-7 links and the builder/decoder threads in the AIM 430.

Figure 20 is a logical representation of the HLR 424. The HLR 424 contains permanent data that is independent of the customer's present location, plus temporary data such as the current location of the system where the mobile unit is registered and the addresses of service centers that have stored short messages for mobile stations. An example of such a message is a request to turn on a voice message waiting lamp indicating that a voice message has been stored for the mobile station user in a voice messaging system. These addresses are erased after the short messages have been delivered.

As shown in Figure 20, the HLR 424 includes customer profiles 460_i for each mobile customer. The customer profile 460_1 includes a customer data module 461. The customer data module 461 includes a customer group identification, which is a four digit number specifying the routing translations index for the customer. The number must be previously configured in a routing translations data base via a routing administration window. The customer data module 461 also includes the International Mobile Customer Identity (IMSI), the International Mobile Equipment Identity (IMEI) or Electronic Serial Number (ESN), which is the serial number of the handset hardware, and the K_i, or A-key which is the key used for authentication calculations. The customer data module 461 also includes the name of the customer, the language for customer announcements, a three to five digit carrier ID identifier for long distance carrier code associated with the customer, a check box for calling card features and a prepaid feature. A call offering module 462 includes an indication of current features

such as call forwarding unconditional (CFU), call forward busy (CFB), call forwarding no reply (CFNRy), and call forwarding not reachable (CFNRc), and call forwarding default (CFD).

A VLR/MSC data module 463 indicates the VLR in and the MSC associated with the current area of operation of the customer. A personal identification number (PIN) data module 464 indicates if the customer uses a PIN when accessing the system for calling card or long distance calls and the four digit PIN number associated with the customer. A protocols module 465 is used for multi-mode customers to determine the capabilities of the customers' units. The protocols may include, but are not limited to, TDMA, CDMA, GSM and AMPS. A call restriction module 466 stores features for restricting the calling capabilities of the customer to and from the network. The call restriction features include baring of all outgoing calls, suspended service (no calls allowed), baring of all outgoing international calls, baring of all incoming calls, baring of all outgoing international calls except those to the home PLMN country and baring incoming calls to a customer when they are roaming to another system.

A call features module 467 indicates the set of features allocated to a customer. The call features include call hold, multi-party calling, 3-way calling, roaming, call waiting and access to sending and receiving short messages. A line identification module 468 identifies features that provide/restrict calling and called number information to various parties in a call. The line identification features include calling line ID presentation, calling number presentation, connected line ID presentation, calling line ID restriction, calling number restriction, and connected ID restriction.

A message center data module 469 provides for storage of short messages pending delivery to a customer's mobile unit.

The HLR 424 may also include an authentication center. The authentication center provides authentication and encryption parameters to insure that a mobile customer cannot falsely assume the identity of another mobile customer. The

authentication center also provides data for encrypting the voice or data and control signals transmitted via the air between the mobile station and the serving base station subsystem. A GSM reference model prescribes digital communications over the radio channels. Since it is possible to surreptitiously listen to these channels, encryption becomes desirable for the link between the mobile station and the radio receiver at a base station serving that mobile station. Any public or proprietary encryption algorithm known in the art can be used with the aircore platform 200.

The calculations for the authentication center use the secret key information associated with the subscriber and the protocol specific calculations. The HLR 424 pre-processes these authentication calculations and stores them as part of the subscriber profile. As required, this information is shared with the servicing MSC/VLR to authenticate the mobile unit as it accesses the system.

The VLR 422 contains current data for each active mobile customer, including that customer's mobile station present or most recently known location area, the mobile unit's on/off status, and security parameters. The VLR 422 is logically constructed in the same manner as the HLR 424.

The HLR and VLR databases both simultaneously accommodate customer profiles from any interface protocol. There are two significant classifications of profile types, based on the intersystem protocol used to transmit and receive profile information over the wireless network. Both GSM and IS-41 based networks share common information in the customer profile structures, but each profile type also requires fields and information that are unique to that particular protocol type. The HLR and VLR databases provide for this by an internal structure that uses a common top level header for the common data and then protocol specific attachments. This internal structure is shown in Figure 21. A GSM side 417 and an IS-41 side 419 are used with the VLR and HLR databases. A common data header 427 is used for both GSM and IS-41 profile information. A GSM specific data area 428 is used for GSM specific data. An IS-41 specific data area 429 is used for IS-41 specific data. The common data header 427 allows the two sides of the database to use common search

routines while the specific data areas allows for the storage of data that pertains to a specific protocol alone.

A description of the timers used by the MSC 210 will now be provided. A call proceeds from initiation to connection through a series of steps. The time associated with this call set up and connection is usually short. Nonetheless, one or more voice channels may be reserved at the start of the call set up. If the call will not connect, some mechanism is desirable to release these resources as quickly as possible so that they may be used by other customers. Furthermore, during the time that the mobile unit is held waiting for an incoming call, the mobile unit cannot call out or receive other incoming calls. To free up resources and to release the mobile unit, the TMR 437, in conjunction with the TIM 406 (see Figure 10) includes a number of timers that may be established at various points in the call set up and connect process. The timers are generally set based on a message from the AMH 431 or similar interface.

A timer may be set when a device handler such as the device handler 510 requests a BSC 105 to assign a channel. In this case, the AMH 431 sends a message to the TMR 437 to set the timer. If an assignment is not completed within the time limit of the timer, the call connection process ends. If the assignment is completed before expiration of the timer, the AMH 431 sends a message to the TMR 437 to release the timer.

A timer may be associated with a connect message sent to the BSC 105 by a device handler. If a connect acknowledgment message is received by the device handler, the AMH 431 will send a timer release message, allowing the call connection to complete. Similarly, a timer may be set to time out a make call command, a paging message for a mobile terminated call, a disconnect message (GSM) or release message IS-634) for PSTN and mobile originated calls, and a clear command to release a channel during a call disconnect sequence. Other timers may be used to ensure resources are returned for assignment to other calls.

Managing the location of a customer ensures the proper connection of the customer's mobile unit for both mobile initiated calls and mobile terminated calls. In

Figure 22, the authentication and registration (ARS) 434 thread is shown in communication with the common memory 439. The common memory 439 includes the data relevant to the mobile unit and the state machine relevant to the protocol and the transaction being performed. The ARS 434 maintains communications with the AMH 431 and the IMH 432 to track ongoing transactions, to compare SRES, to send TMSI to the mobile unit and to provide ciphering information to the AMH 431. The IMH 432 provides connections to the VLR 422 and HLR 424 for obtaining customer profile information.

The call processing module (CPM) 414 processes calls according to one of several state machines. A state machine exists for each half of every call processed through the aircore platform 200. A separate state machine exists for mobile originated call processing, PSTN originated call processing and mobile terminated call processing, for example. Figures 23-25 are examples of state machines used in processing calls at the aircore platform 200. Figure 23 is a state machine 600 for mobile originated call processing. In Figure 23, eight states are possible: idle (S1), wait for UUI (S2), wait for page response (S3), wait for alert (S4), wait for connect (S5), voice (S6), wait for handoff confirm (S7), tone and announce (S8), and wait for call cleared (S9). The state machine 600 shows the allowed transitions between states. Starting in idle S1, the state machine 600 can transition to state wait for UUI S2 or wait for call cleared S9. The state machine 600 transitions to wait for UUI S2 based on reception of the mobile customer's profile when a CALL_RECEIVED message is received. The state machine 600 transitions from idle S1 to wait for call cleared S9 based on the mobile customer profile indicating a particular call restriction or if the call fails before routing. With the authentication previously set up with the A-interface protocol, this transition may not be possible.

In the wait for UUI state S2, the state machine 600 can transition to the wait for alert state S4. This transition is based on receiving the ROUTE_CALL message. The aircore platform 200 proceeds with making the call out to the called party if the call type is direct dial (DD) in the routing translations or when a call delivery to a

mobile unit or another system is required. The CPM 414 then sends a MAKE_CALL message. Next, the state machine 600 can transition from the wait for UUI state S2 to the wait for page response S3 based on receiving a ROUTE_CALL message. A PAGE_MOBILE message is sent to the PAG 435. The transition to this state is based on a call type of MOB in the routing translations and finding that the called mobile unit is operating in the aircore system. The state machine 600 transitions from the wait for UUI state S2 to the tone and announce state S8 if the dialed number received from the originating mobile unit fails to translate properly or if there is a restriction on the called mobile unit. The originating mobile unit is then connected to a tone. This transition could also occur by the CPM 414 receiving a PAGE_RESPONSE message with a time out indication. Finally, the wait for UUI state S2 can transition to the wait for call cleared state S9 based on receiving a disconnect from the mobile unit. When the message CALL_DISCONNECTED is received at the CPM 414, a CLEAR_CALL message is sent.

The state machine 600 transitions from the wait for page response S3 to the wait for alert state S4 based on receiving a PAGE_RESPONSE message. A MAKE_CALL message is then sent and the CPM 414 proceeds with an ISDN state machine 600. The wait for page response state S3 transitions to the tone and announce state S8 along transition path T8 based on receiving a time out for a page response. The CPM 414 then provides a time out announcement or tone to the calling party. The state machine 600 transitions from the wait for page response state S3 to the wait for call cleared state S9 along transition path T9 based on receiving a disconnect from the originating mobile unit. A CALL_DISCONNECTED message is received at the CPM 414 and a CLEAR_CALL message is sent. The PAG thread 435 will time out and clear the page request data for the call.

The state machine 600 transitions from the wait for alert state S4 to the wait for connect state S5 along transition path T10 based on receiving an alerting indication from the called party. The alerting indication is passed to the mobile customer's side of the call. The CPM 414 receives the CALL_ALERTING message

from the called party and sends an ALERT_CALL to the originating mobile unit. The transition from the wait for alert state S4 to the voice state S6 occurs along transition path T11 based on receiving a connect indication from the called party. The protocol allows a CONNECT message to be received without receiving alerting. The CPM 414 receives a CALL_CONNECTED message from the called party and sends a CONNECT_CALL message to the originating mobile unit. The transition from the wait for alert state S4 to the tone and announce state S8 is along transition path T12. This transition occurs for two possible reasons. First, the transition may be based on a time out waiting for the alerting indication. The called party is cleared from the call and the mobile customer is connected to an announcement or tone. The CPM 414 sends a CLEAR_CALL message to the called party. Second, the transition may be based on receiving a disconnect from the called party with "user busy." The originating mobile unit is sent an announcement and the called party is released from the call. The CPM 414 receives a CALL_DISCONNECTED message from the called party and sends a CLEAR_CALL message to the called party. Finally, the transition from the wait for alert state S4 to the wait for call cleared state S9 occurs along transition path T13 if the originating mobile customer disconnects from the call before the CPM 414 receives the alerting indication from the called party. Clearing both parties is initiated. The CALL_DISCONNECTED message is received from the originating mobile unit. The CPM 414 sends a CLEAR_CALL message to both parties.

The state machine 600 may transition from the wait for connect state S5 to the voice state S6 along transition path T14 based on receiving connect indication from the called party. The connect indication is passed to the mobile customer. The CPM 414 received a CALL_CONNECTED message from the called party and sends a CONNECT_CALL message to the originating mobile unit. Transition from the wait for connect state S5 to the tone and announce state S8 occurs when a time out occurs waiting for the connect. The called party is cleared from the call and the mobile customer is connected to a tone or announcement. The CPM 414 sends a

CLEAR_CALL message to the called party. Transition from the wait for connect state S5 to the wait for call cleared state S9 occurs along transition path T16 if the originating mobile subscriber disconnects from the call before the CPM 414 receives the connect indication from the called party. Clearing both parties is initiated. The CPM 414 receives a CALL_DISCONNECT message from the originating mobile unit and sends a CLEAR_CALL message to both parties.

The state machine 600 transitions from the voice state S6 to the wait for called clear state S9 along transition path T17 based on receiving a disconnect indication from either party. Call clearing is initiated for both parties on the call. A CALL_DISCONNECTED message is received from one of the parties. The CPM 414 sends a CLEAR_CALL message to both parties. Transition from the voice state S6 to the wait for hand off confirm state S7 occurs along transition path T18 based on receiving a hand off request from the HOP 416 subsystem and having a B-channel to allocate to the target BTS for the hand off. The CPM 414 receives a HAND_OFF request from the HOP 416 and sends a MAKE_CALL message with a hand off indicating to establish the target channel. Finally, the voice state S6 transitions back to the voice state S6 along transition path T19 based on receiving a hand off request and not having a B-channel available to the BTS.

The state machine 600 transitions from the wait for hand off confirm state S7 to the voice state S6 along transition path T20 based on three possible events. First, the CPM 414 receives a hand off confirmation from the serving BTS. This indicates the mobile unit has confirmed the hand off and is in transition to the target BTS. The voice connection is switched to the target BTS at this point. The CPM 414 receives a HAND_OFF_CONFIRM message and sends a CLEAR_CALL to the old serving channel. The voice path in connected to silence until the CALL_CONNECTED message is received on the target channel. Second, the CPM 414 receives a hand off confirmation with a negative indication (failed). This indicates that the mobile unit is not going to the target channel. The CPM 414 starts a disconnect sequence to release the target channel. The CPM 414 then sends a CLEAR_CALL message to the target

channel. Third, the CPM 414 receives a failure on the channel setup with the target BTS. The transition to the voice state S6 occurs and the CPM 414 initiates or continues with the disconnect sequence with the target BTS channel. The CPM 414 sends a CLEAR_CALL message to the target channel. Transition from the wait for confirm state S7 to the wait for call cleared state S9 occurs along transition path T21 based on receiving a disconnect from either party while a target BTS channel is being established for the hand off. The CPM 414 initiates clearing all resources and transition. The CPM 414 receives a CALL_DISCONNECTED message and sends a CLEAR CALL message to the parties.

The state machine 600 transitions from the tone and announce state S8 to the wait for call clear state S9 along transition path T22 based on the originating mobile unit disconnect indication being received from the CPM 414. This can occur as a result of a time out after the tone or an announcement is played and a disconnect is not received. In this case, the CPM 414 initiates the disconnect with the mobile customer. The CPM 414 initiates the disconnect with the mobile customer. The CPM 414 either receives a CALL_DISCONNECTED message and sends a CLEAR_CALL message or the CPM 414 receives a time out and sends a CLEAR_CALL message.

The state machine 600 transitions from the wait for call cleared state S9 to the idle state S1 along transition path T23 based on both parties confirming they are cleared from the call. In cases where there is no other party involved in the call, the confirmation of the clearing of the party is implied by the fact that the cell never existed. This transition takes place when the call is completely cleared. The CPM 414 receives a CALL_CLEARED message from the originating mobile unit.

Figure 24 is a state machine 601 for PSTN originated call processing. In the state machine 601, the wait for UUI state S2 and the wait for handoff confirm state S7 are not allowed states. The state machine 601 transitions from the idle state S1 to the wait for page response state S3 along transition path T24 based on determining the need to page the mobile customer. The CPM 414 sends a PAGE_MOBILE message to the PAG thread 435. Transition from the idle state S1 to the wait for alert state S4

occurs along transition path T25 based on determining that the mobile customer is located on another system and the aircore platform 200 has received a routing number to call the current serving switch. The CPM 414 sends a MAKE_CALL message using the TLDN (MSRN GSM). The transition from the idle state 51 to the wait for alert state 54 can also occur under a forwarding condition of the original destination number. Transition from the idle state S1 to the tone and announce state S8 occurs along transition path T26 if the called number received from the originating PSTN party fails to translate properly or if there is a restriction on the called mobile unit. In this case the originating PSTN party is connected to a tone or announcement. This transition could also occur by the CPM 414 receiving a PAGE_RESPONSE message with a time out indication.

The state machine 601 transitions from the wait for page response state S3 to the wait for alert state S4 along transition path T27 based on receiving a PAGE_RESPONSE message. The CPM 414 sends a MAKE_CALL message and proceeds with the ISDN state machine. Transition from the page response state S3 to the tone and announce state S8 occurs along transition path T28 based on receiving a time out for a page response (i.e., PAGE_RESPONSE message received by the CPM 414 with a time out indication). The CPM 414 provides a time out announcement or tone to the calling party. Transition from the wait for page response state S3 to the wait for call cleared state S9 occurs along transition path T29 based on receiving a disconnect from the originating PSTN party. The CPM 414 receives a CALL_DISCONNECTED message and sends a CLEAR_CALL message. The PAG thread 435 will time out and clear the page request data for the call.

The state machine 601 transitions from the wait for alert state S4 to the wait for connect state S5 along transition path T30 based on receiving an alerting indication from the called party. The alerting indication is passed to the PSTN side of the call. The CPM 414 received a CALL_ALERTING message from the called party and sends an ALERT_CALL message to the originating PSTN party. Transition from the wait for alert state S4 to the voice state S6 occurs along transition path T31 based

on receiving a connect indication from the called party. The protocol allows reception of the connection without receiving alerting. The CPM 414 receives a CALL_CONNECTED message from the called party and sends a CONNECT_CALL to the originating PSTN party. Transition from the wait for alert state S4 to the tone and announce state S8 occurs along transition path T32 for two possible reasons. First, transition may be based on a time out waiting for the alerting indication. The called party is cleared from the call and the PSTN party is connected to an announcement or tone. The CPM 414 sends a CLEAR_CALL message to the called party. Second, transition may be based on receiving a disconnect from the called party with "user busy." The originating PSTN party is sent an announcement and the called party is released from the call. The CPM 414 receives a CALL_DISCONNECTED message from the called party and sends a CLEAR CALL message to the called party. Transition from the wait for alert state S4 to the wait for call cleared state S9 occurs transition path T33 if the originating PSTN party disconnects from the call before the CPM 414 receives the alerting indication from the called party. Clearing of both parties is initiated. The CPM 414 receives a CALL_DISCONNECTED message from the originating PSTN party and sends a CLEAR_CALL message to both parties.

The state machine 601 transitions from the wait for connect state S5 to the voice state S6 along transition path T34 based on receiving connect indication from the called party. The connect indication is passed to the PSTN party. The CPM 414 receives the call connected message from the called party and sends the CONNECT_CALL message to the originating PSTN party. Transition from the wait for connect state S5 to the tone and announce state S8 occurs along transition path T35 when a time out occurs waiting for the connect. The called party is cleared from the call and the PSTN party is connected to a tone or announcement. The CPM 414 sends a CLEAR_CALL message to the called party. Finally, transition from the wait for connect state S5 to the wait for call cleared state S9 occurs along transition path T36 if the originating PSTN party disconnects from the call before the CPM 414 receives the connect indication from the called party. Clearing both parties is

initiated. The CPM 414 receives a CALL_DISCONNECTED message from the originating PSTN party and sends the CLEAR_CALL message to both parties.

The state machine 601 transitions from the voice state S6 to the wait for call cleared state S9 along transition path T37 based on receiving a disconnect indication from either party. Call clearing is initiated for both parties. The CPM 414 receives the CALL_DISCONNECTED message from one of the parties. The CPM 414 then sends the CLEAR_CALL message to both parties.

The state machines 601 transitions from the tone and announce state S8 to the wait for call cleared state S9 along transition path T38 based on the originating mobile unit disconnect indication being received from the CPM 414. This can also occur as a result of a time out after the tone or announcement is played and a disconnect is not received. In this case, the CPM 414 initiates the disconnect with the mobile customer. The CPM 414 either receives a CALL_DISCONNECTED message and sends a CLEAR_CALL message or the CPM 414 receives a time out and sends the CLEAR_CALL message.

The state machine 601 transitions from the wait for call cleared state S9 to the idle state S1 along transition path T39 based on both parties confirming they are cleared from the call. In cases where there is no other party involved in the call the confirmation of the clearing of the party is implied by the fact that it never existed. Transition takes place when the call is completely cleared. The CPM 414 receives the CALL_CLEARED message from the originating mobile unit.

Figure 25 shows a state machine 602 for a mobile terminated call processing. As shown in Figure 25, the states wait for UUI S2, wait for page response S3 and tone and announce S8 are not used in a mobile terminated call processing scenario. The state machine 602 transitions from the idle state S1 to the wait for alert state S4 along transition path T40 based on reception of a valid PAGE_RESPONSE message. The CPM 414 sends a MAKE_CALL message to the terminating mobile unit. The idle state S1 returns to the idle state S1 along transition path T41 based on a page time out,

or failure in routing. The calling party is sent to an announcement or the call is forwarded based on the customer's feature profile.

State machine 602 transitions from the wait for alert state S4 to the wait for connect state S5 along transition path T42 based on receiving an alerting indication from the terminating mobile customer. The alerting indication is passed to the calling party's side of the call. The CPM 414 receives a CALL_ALERTING message and sends a ALERT_CALL message to the calling party. Transition from the wait for alert state S4 to the voice state S6 occurs along transition path T43 based on receiving a connect indication from the called mobile unit. The protocol allows receipt of a receive connect message without receiving alerting. The CPM 414 receives a CALL_ CONNECTED message from the called party and sends a CONNECT_CALL message to the calling party. Transition from the wait for alert state S4 to the wait for call cleared state S9 occurs along transition path T44 if the calling party disconnects from the call before the CPM 414 receives the alerting indication from the mobile customer. Clearing both parties is initiated. The CPM 414 receives a CALL DISCONNECTED message from the calling party and sends a CLEAR_CALL message to both parties. In addition, in time out cases where the calling party is sent to an announcement, the called mobile unit will receive a CLEAR_CALL message from the CPM 414 and make the transition.

The state machine 602 transitions from the wait for connect state S5 to the voice state S6 along transition path T45 based on receiving a connect indication from the called mobile customer. The connect indication is passed to the calling party. The CPM 414 receives a CALL_CONNECTED message and sends a CONNECT_CALL message to the calling party. Transition from the wait for connect state S5 to the wait for call clear state S9 occurs along transition path T46 that the calling party disconnects from the call before the CPM 414 receives the connect indication from the mobile customer. Clearing both parties is initiated. The CPM 414 receives a CALL_DISCONNECTED message from the calling party. The CPM 414 then sends a CLEAR_CALL message to both parties. In addition, in time out cases where the

calling party is sent to an announcement, the called mobile unit will receive a CLEAR_CALL message from the CPM 414 and make the transition.

The state machine 602 transitions from the voice state S6 to the wait for call cleared state S9 along transition path T47 based on receiving a disconnect indication from either party. Call clearing is initiated for both parties in the call. The CPM 414 receives a CALL_DISCONNECTED message from one of the parties and sends a CLEAR_CALL message to both parties. Transition from the voice state S6 to the wait for hand off confirm state S7 occurs along transition path T48 based on receiving a hand off request from the HOP subsystem 416 and having a B-channel to allocate to the target BTS for the hand off. The CPM 414 receives a hand off request message from the HOP 416 and sends a MAKE_CALL message with a hand off indication to establish the target channel. Transition from the voice state S6 back to the voice state S6 occurs along transition path T49 based on receiving a hand off request and not having a B-channel available to the BTS.

The state machine 602 transitions from the wait for hand off confirm state S7 to the voice state S6 along transition path T50 in one of three situations. First, the CPM 414 receives a hand off confirmation from the serving BTS. This indicates the mobile unit has confirmed the hand off and is transitioning to the target BTS. Voice connection is switched to the target BTS at this point. The CPM 414 receives the HANDOFF_CONFIRM message and sends the CLEAR_CALL message to the old serving channel. The voice path is connected to silence until the CALL_CONNECTED message is received on the target channel. Second, the CPM 414 receives a hand off confirmation with a negative indication (failed). This indicates that the mobile unit is not going to the target channel. A disconnect sequence to release the target channel is started and the CPM 414 sends a CLEAR_CALL message to the target channel. Third, the CPM 414 receives a failure of the channel set up with the target BTS. Transition to the voice state S6 in initiation or continuation of the disconnect sequence with the target BTS channel begins. The CPM 414 sends a CLEAR_CALL message to the target channel. Transition from the hand off confirm

state S7 to the wait for call cleared state S9 occurs along transition path T51 based on receiving a disconnect from either party while a target BTS channel is being established for the hand off. The CPM 414 initiates clearing all resources and transition. The CPM 414 receives a CALL_DISCONNECTED message and sends a CLEAR_CALL message to all parties.

The state machine 602 transitions from the wait for call cleared state S9 to the idle state S1 along transition path T52 based on both parties confirming they are cleared from the call. In cases where there is no other party involved in the call, the confirmation of the clearing of this party is implied by the fact that a call never existed. This transition takes place when the call is completely cleared. The CPM 414 receives a CALL_CLEARED message from the originating mobile unit.

The aircore platform 200 uses a common facility state machine for tracking the states and conditions of external connections or trunks. Two portions of the state are tracked. Each facility has a near end and a far end state. The near end state represents the internal aircore state for the facility. The far end state represents the state of the facility as reported by the connected system. This state machine tracking applies to all aircore interfaces including traffic channels and signaling channels. Like call processing, these maintenance procedures are generic in the aircore platform 200 regardless of the interface.

Figure 26 is a aircore near end facility maintenance state machine 604. The state machine 604 includes the states not configured (S10), blocked (S11), unblocked pending (S12), unblocked (S13), call processing (S14), blocked pending (S15), and maintenance (S16).

Figure 26 also shows the transitions between the states of the state machine 604. The state machine 604 transitions from the state not configured S10 to the blocked state S11 along transition path T60 when a facility is added to the configuration and is enabled.

The state machine 604 transitions from the blocked state S11 to the unblocked pending state S12 over transition path T61 when either operator initiated or automatic

recovery occurs which requests that the destination device handler bring the requested facility to an unblocked (in service) state. Transition from the blocked state S11 to the maintenance state S16 occurs along transition T62 when the facility is taken to a maintenance state to perform a maintenance or test operation. This transition is based on an operator action. Transition from the blocked state S11 to the not configured state S10 occurs along transition path T63 when the facility is disabled and/or removed from the system configuration.

The state machine 604 transitions from the unblocked pending state S12 to the unblocked state S13 over transition path T64 when a maintenance action is confirmed by the device handler. The facility is now in service. Transition from the unblocked pending state S12 to the blocked pending state S15 occurs over transition path T65 when a maintenance action is denied by the device handler or aborted by an operator action.

The state machine 604 transitions from the unblocked state S13 to the call processing state S14 along transition path T66 when the facility is allocated and will be used for call processing. Transition from the unblocked state S13 to the blocked pending state S15 occurs along transition path T67 when either operator initiated or automatic maintenance action from the device handler. Transition also occurs based on other internal action requests that the destination device handler bring the requested facility to a blocked (off-line) state.

The state machine 604 transitions from the call processing state S14 to the unblocked state S13 over transition path T66 when the facility is released from being used in call processing. Transition from the call processing state S14 to the blocked pending state S15 occurs over transition path T69 when a maintenance action is either operator initiated or automatic from the device handler or other internal action requests that the device destination handler bring the requested facility to a blocked (off-line) state.

The state machine 604 transitions from the blocked pending state S15 to the blocked state S11 over transition path T70 when a maintenance action to take facility

off-line is confirmed by the device handler. In a case where the device handler does not respond, the state may be reached by default of no response.

The state machine 604 transitions from the maintenance state S16 to the blocked state S11 over transition path T71 when the maintenance action on the facility is completed. Operator action is required to transition the state back to the blocked state S11.

In addition to monitoring the near end state of the system facilities, the aircore platform 200 also maintains the far end state of facilities where applicable. The far end state represents the status of a facility at the connected system side. The far end state and near end state are used together to determine the overall operational state.

Figure 27 shows the aircore far end facility maintenance state machine 605. In Figure 27, the states are not configured (S17), blocked (S18), unblocked (S19), and unknown (S20).

The state machine 605 transitions from the not configured state S17 to the blocked state S18 along transition path T80 when a facility is added to the configuration and enabled.

The state machine 605 transitions from the blocked state S18 to the unblocked state S19 over transition path T81 when an unblocking request is received from the far end. Confirmation is then sent back with an unblocking acknowledgment message. Transition from the blocked state S18 to the unknown state S20 occurs over transition path T82 when a discrepancy has been detected between the state reported by the far end and the stored far end state for the facility in aircore platform 200. The blocked state S18 transitions to the not configured state S17 over transition path T83 when the facility is disabled and/or removed from the system configuration.

The state machine 605 transitions from the unblocked state S19 to the blocked state S18 over transition path T84 when a blocking request message is received from the far end. Confirmation is sent back with the blocking acknowledgment message. Transition from the unblocked state S19 to the unknown state S20 occurs over

transition path T85 when a discrepancy has been detected between the state reported by the far end and the stored far end state for the facility in the aircore platform 200.

The state machine 605 transitions from the unknown state S20 to the blocked state S18 over transition path T86 when the far end reports the state of the facility is blocked. Transition from the unknown state S20 to the unblocked state S19 occurs over transition path T87 when the far end reports the state of the facility is unblocked.

Hand off processing occurs when an active mobile unit transitions from a wireless region supported by one base station to a wireless region supported by a second base station. Hand off processing may also occur as a mobile unit transitions from one cell site within a wireless region to another sell site.

Figure 28 shows an aircore wireless environment 106 in which the aircore platform 200 functions as a mobile switching center (MSC). There are many different protocol scenarios that are possible for hand off processing in the aircore environment 106, including ISDN PRI+ with an AMPS base station, DHD-based (AMPS) base station, IS-634 AMPS, IS-634 TDMA, IS-634 CDMA, GSM, IS-41 Revision B, IS-41 Revision C and GSM mobile application part (MAP). In addition, the processing design of the aircore platform 200 retains the flexibility to easily adapt to other hand off protocols. Finally, the aircore platform 200 may receive hand off requests from multi-protocol mobile units.

In Figure 28, base station controllers (BSCs) 105_1, and 105_2 and base transceiver stations (BTSs), are shown connected to the aircore platform 200 via signal lines 485 and 495, respectively. The BSC 105_1 has an associated wireless region 480 that includes BTSs 481, 482 and 483. The BSC 105_2 has an associated wireless region 490 with BTSs 491, 492 and 493. The mobile unit 112 is active in the wireless region 480 at point A and communicates with a land-line phone 114 via PSTN 120, the aircore platform 200, the BSC 105_1 and the BTS 481.

In the above description, the BTS receives a call from a mobile unit. The mobile unit may be a mobile telephone or a computer with a wireless modem, for

example. In addition, the BSC/BTS may be replaced in some scenarios with a BSS or any other base station configuration.

During the course of a call, the mobile unit 112 transitions from point A in wireless region 480 to point B in wireless region 490. As a result of this transition, the BTS 105_1 detects that the signal level of the cell has dropped below the minimum to continue the call on the current channel. The BSC 105_1 notifies the aircore platform 200, which begins hand off processing to establish a new cell site using the BSC 105_2. When the new cell site is established, the aircore platform 200 tears down the previous link, thereby freeing up resources for other wireless customers.

In the scenario described above, the BSC 105_1 and 105_2 are both associated with the aircore platform 200 and certain hand off processing functions such as strength measurements are performed by the aircore platform 200. In a scenario involving a base transceiver station coupled to another mobile switching center, the base transceiver stations may perform these hand off processing functions.

As with other processing functions, the software architecture 300 of the aircore platform 200 is designed to use, as much as possible, generic processing for mobile unit hand offs. Thus, communications from the mobile units operating according to different protocols, e.g., GSM, TDMA, CDMA and AMPS are handled in a generic fashion, except where specific differences are required. The message flows associated with these protocols will be described later.

Referring to Figure 10, once a base station detects that the signal level has either dropped below the minimum, or exceeded the maximum, to continue the call on the current channel, hand off processing begins. Measurements are taken of bordering systems to determine the best candidate system, or target base station. The HOP 416 is involved in this for analog protocols and some inter-system hand offs. Otherwise, the step may be handled directly between the base station and the mobile unit. For digital protocols, the base station sends the target information to the HOP 416 for transmission to the CPM 414. For ISDN PRI + and DHD based analog protocols, the HOP 416 determines the appropriate target for the hand off. Next, the CPM 414 is

notified via the HOP 416 of the required hand off and begins establishing a voice circuit to the target system. Once confirmed, the CPM 414 sends the hand off command to the current serving base station. This information is passed to the mobile unit. The mobile unit confirms the reception of the target information and switches to the new frequence and voice path. Upon arrival at the new frequency, the new serving base station passes the confirmation to the CPM 414. The CPM 414 switches the voice path during this process to the new channel and tears down the voice path to the old serving system.

As noted above, the HOP 416 preprocess is limited. After the hand off is in progress, the HOP 416 is no longer involved. Call processing uses the information provided by the HOP 416 to establish appropriate resources to complete the hand off. Call processing is responsible for the control of the remaining portion of the hand off.

For ISDN PRI+ protocol hand offs, a message is sent to the aircore platform 200 from a base station to indicate that a mobile unit requires a hand off. The message specifies a protocol discriminator, a call reference (whose value is assigned in a SETUP message), a message type and a user identification. The aircore platform 200 in turn sends a hand off message request to the base station to request the base station measure a specific frequency. Finally, the base station sends a message to the aircore platform 200 to report the measured strength of the signal recorded on the base station.

ISDN PRI+ processing requires that the HOP 416 accept a hand off request from the DHI 503. Appropriate hand off related information, including call reference and RF channel, for example, is stored in the air core platform 200. The call reference is a number that is retrieved from the device handler thread data that is initially stored when call setup takes place. The RF channel is also retrieved from the device handler thread data. The air core platform 200 then sends measurement requests to appropriate boarder cells, sets a measurement request timer, and processes responses from the base station.

For DHD based protocol hand offs, the HOP 416 accepts a hand off request from one of the device handlers in the aircore platform 200. The appropriate hand off related information, including the call reference and RF channel, for example, are stored. The aircore platform 200 allocates a voice channel and sends measurement requests (SCANs) to the appropriate border cells, sets a measurement timer, and processes responses received from the base stations. For base stations not chosen for hand off, the aircore platform 200 initiates a channel release. If a suitable target cell is determined, the HOP 416 send the information to the CPM 414 for hand off.

For DHD based protocol hand off processing, a voice channel is assigned to each base station when the measurement process takes place. For example, if three base stations border the current wireless system and a measurement is to be taken, a voice channel is explicitly reserved in each base station. When the target base station is chosen, the voice channels in the other base stations must be released. To accomplish this release, the device handlers will allocate and release the appropriate channels for the measurements in accordance with commands sent by the HOP 416. If an allocation fails or there are no channels available in a base station, the device handlers send allocation failure events to the HOP 416, and the HOP 416 removes the base station from the candidate list for the current hand off.

IS-634 analog hand off processing requires the HOP 416 to send a measurement request to the AIM 430. The measurement request is then sent to appropriate border cells. The measurement requests are sent back to the requesting base station, and the information is forwarded to the HOP 416, for determination of the target cell.

The strength measurement message is transferred to cells that are listed in a Cell Identifier List parameter that is sent in the message. The HOP 416 stores the reference number against the requesting base station so the return messages find the correct base station. The reference number is timed in accordance with a base station timer for measurement collection. Responses received after timer expiration are discarded.

IS-634 TDMA hand off processing requires that the HOP 416 determine, based on information received from the base station in a hand off required message, the appropriate candidate cell. The HOP 416 then sends the appropriate information to the CPM 414. If the HOP 416 does not find a suitable target cell, the hand off is aborted.

IS-634 CDMA hand off processing requires the that HOP 416 determine an appropriate target cell, based on information received by the HOP 416 from the base station. The HOP 416 aborts the hand off if a suitable target cell is not determined.

GSM hand off processing requires that the HOP 416 use information received from the base station in the hand off required message to determine appropriate target cells. Once again, the HOP 416 aborts the hand off if a suitable target cell is not located.

For hand off processing from a multiple protocol base station, the message flows to the HOP 416 indicate the appropriate protocol of the mobile unit. For intersystem hand offs, messages related to the intersystem hand off preprocessing are sent from the HOP 416 to the IMH 432 and from the IMH 432. The border cell for measurement may be reached in the same manner as sending a message to multiple cell sites, except that the messages are intersystem. Therefore, the messages are sent to the IMH 432, or are received from the IMH 432 instead of the AIM 430 base station threads, DHI 503 or DHD 501.

Each cell supporting hand off in the aircore system 106 must have an associated list of border cells that are contacted in the event of a hand off attempt. These cells may have an identity that ties the cells to a link. These cells also have a protocol that the HOP 416 and the CPM 414 can use for determining message destination, supported protocols, and associated trunk groups, all of which may be used for new voice circuit allocations.

Because the aircore platform 200 is capable of processing a number of different protocol messages, some mechanism must be provided to determine the correct protocol. For messages received from a single-protocol BSS, the aircore

platform 200 determines the correct protocol by reference to the protocol established for that particular BSS. The BSS is then associated with a signaling link mechanism that connects the BSS to the MSC 210. The link may be a SS-7 base, TCP/IP, LAPD, CAS and ATM, for example. The MSC 210 associates the type of protocol supplied by the BSS to any incoming messages received from the BSS. The actual protocol for the base station is determined when the link to the BTS or BSS is brought into service. One example is when the DH-7 510 spawns a thread connecting the BSS to the MSC 210.

To ensure signaling messages used with the aircore platform 200 perform the same generic function across protocols, tables of messages may be used for different aircore platform functions. The table that follows shows some of the messages used for call processing in the aircore platform 200, and the accompanying messages according to specific protocols.

Internal AireCore Call Processing Event	**GSM (Euro and US)**	**IS-634 CDMA**	**IS-634 TDMA**	**IS-634 AMPS**
CPM_PAG_PAGE_MOBILE	Page Request	Page Request	Page Request	Page Request
PAG_CPM_PAGE_RESPONSE	Page Response	Page Response	Page Response	Page Response
MAKE_CALL	Setup	Setup	Setup	Setup
CALL_RECEIVED	Setup	Setup	Setup	Setup
ROUTE_CALL	Assignment Complete	Assignment Complete	Assignment Complete	Assignment Complete
ALERT_CALL	Alerting	Alerting	Alerting	Alerting
CALL_ALERTING	Alerting	Alerting	Alerting	Alerting
CONNECT_CALL	Connect	Connect	Connect	Connect
CALL_CONNECTED	Connect	Connect	Connect	Connect
CLEAR_CALL	Disconnect	Disconnect	Disconnect	Disconnect
CALL_DISCONNECTED	Disconnect	Release	Release	Release
CLEAR_CALL	Release	Release/Release Complete	Release/Release Complete	Release/Release Complete
CALL_CLEARED	Release Complete	Release Complete	Release Complete	Release Complete

Calls may fall into one of several scenarios, including mobile originated (a mobile unit originates the call), mobile terminated (a call to a mobile unit) and PSTN originated, for example. Mobile originated calls may be received at the MSC and may be originated at another wireless system (intersystem). Mobile originated calls may also be received at a BTS and may then be passed to the MSC.

The aircore platform 200 initiates a location update sequence to register a mobile unit with the aircore platform 200. A customer profile is retrieved from the VLR 422 or HLR 424 as necessary. Once a customer profile is retrieved, the procedures for call setup across the protocols is generic. The use of a standard internal set of procedures allows the call processing of the aircore platform 200 to be independent of the type of interface used when establishing the call. The events that are specific to a particular protocol are handled by individual components of the AIM 430. A CALL_RECEIVED message announces arrival of an incoming call to the CPM 414. When this message is sent, the customer profile is included as well as the selected traffic channel. The CALL_RECEIVED message is sent based on proper profile retrieval, authentication and channel selection. A ROUTE_CALL message is sent to the CPM 414 as an indication that the call may be routed to the network since the traffic channel allocation to the originating mobile unit was successful. The ROUTE_CALL message is sent based on proper channel assignment for the call. An ALERT_CALL event is received from the CPM 414 as an indication that the far end of the call is in the alerting state. When this event is received, an alert message is sent to the mobile unit. A CONNECT_CALL event is received as an indication that the far end has connected the call. This indication is passed on to the mobile station in the connect message. The above four events are used between the CPM 414 and all other subsystems for call originations in the system.

Mobile termination also uses a set of generic events and/or messages. However, mobile termination is more of a challenge than mobile origination, since the current operating mode of a subscriber is not known prior to querying the relative

databases. Similar to the mobile origination procedure and the location updating procedure, mobile termination is generic for all base station-type interfaces regardless of the protocol. The first query is to the HLR 424 via the IMH 432. Call processing sends an event to the IMH 432 requesting the current location of the customer and how to reach the customer. This request is sent without indication of the intrasystem protocol to use. The IMH 432 utilizes the MIN/MSISDN to HLR mapping table to determine a protocol and location of the HLR in the network.

For an internal HLR, the event is built and sent to the HLR 424 for processing. The protocol indicator is set based on the mapping table and a search is performed to locate the customer profile in the HLR database. If the customer profile is not found, the HLR 424 can optionally query the opposite side of the database in the case where the phone supports multiple modes and protocols. Once found, the VLR 422 is contacted (if not local) via standard procedures, such as ROUTE_REQUEST or PROVIDE_ROAMING_NUMBER.

For call tear down, the aircore platform 200 is based on the ISDN model for call release. This scenario is a three message sequence beginning with the requesting interface presenting notification of a disconnect. The notification is followed with a two event exchange with all involved subsystems for the call to command the release of the call and a return message to confirm the release. Low level processing in the aircore platform 200 ranges from changing the state of supervision bits to a two or three message exchange.

Figure 29a shows the basic components of the aircore platform 200 that are involved in call processing in the above scenarios. As shown in Figure 29a, calls to the aircore platform 200 may be received at a device handler such as the DH-7 510. The device handler DH-7 510 may communicate with the IMH 432 and the AMH 431. The VLR 422 and the HLR 424 and AC/AuC (not shown) may be addressed by the IMH 432 to retrieve customer-specific data and to perform other functions, including customer location, for example. The CPM 414 communicates with the ARS 434, the IMH 432 and the PAG 435.

The components shown in Figure 29a communicate via a set of generic messages. These messages indicate receipt of a call, authentication, call routing and call connection, for example.

To ensure proper tracking of a call and the call's processing, whenever a call comes into the aircore platform 200, the AMH 431 receives a notification from the DH-7 510. The AMH 431 accesses the decoder thread to decode the incoming message and to determine the appropriate action. If the message is the first message associated with a call, the AMH 431 allocates an area in the common memory 439, with an index to that area. For the duration of the call processing and the call, the designated area will be used as needed during the transaction processing. For example, the designated area includes the customer identification number and the base station identification.

The AMH 431 can spawn threads unique to base station protocols such as GSM or RDMA, TDMA, or AMPS. The AMH 431 may also spawn different threads depending on the manufacturer of a mobile unit.

The IMH 432 works in a fashion similar to that of the AMH 431 in that the IMH 432 spawns different threads, depending on the protocol required for the system (GSM or IS-41). When the IMH 432 deals with internal events, it shares the index and memory space used by the associated AMH 431. The IMH 432 pulls the message from the memory space of the common memory 439 created by the AMH 431, using the index created by the AMH 431.

The IMH 432 also processes events without the involvement of an AMH 431 thread. For these situations, the index and memory area are allocated by the IMH 432 thread. Memory and index allocation are coordinated within the AIM 430 subsystem.

The ARS 434 communicates with the VLR 422 via the IMH 432 thread to retrieve the requisite information to authenticate the subscriber and determine the validity of the transaction. The processing of the ARS 434 thread is made generic.

The PAG 435 thread tracks the outstanding page requests that are in process for the system. The PAG 435 thread receives incoming PAGE_MOBILE events from

the CPM 414 when a mobile unit is to be paged on the aircore system. The PAG 435 thread determines the appropriate base station resources that should be sent the PAGE message. The PAGE_REQUEST message is then communicated to the appropriate AMH 431 threads for processing. In a multi-protocol environment, the decision on the base stations that receive the PAGE_REQUEST event is based on the last known technology that the mobile unit was operating on. If a mobile unit has GSM and CDMA capabilities, and the last activity for the mobile unit was on the GSM portion of the system, the PAG 435 thread will process this as a GSM based paging. If however, there is not a last known technology for the mobile unit, all technologies within the mobile unit's capabilities are paged. If the mobile unit referenced above did not have a last known technology, both the CDMA and the GSM based paging would take place. Once the PAGE_RESPONSE message is received, the AMH 431 thread decodes the message and sends the decoded data, via the common memory 439 to the PAG 435 thread where an association is made between the incoming PAGE_RESPONSE and the previous outgoing PAGE_REQUEST messages. Based on the responding base station, the appropriate technology can be determined. The determination of the proper protocol at this point is much like the determination used for mobile originated actions. The responding base station determines the protocol based on its capabilities that were known when the interface to the base station was brought into service.

Call processing also uses a common reference scheme to track all events associated with a call. This scheme is illustrated in Figure 29b. Each call placed with the aircore platform 200 leads to creation of a session 490 with a session object header 491. The session object header 491 is created based on an index number generated from the board, span, and channel used for the first party involved in the call. Board, span and channel is a reference created relative to the physical interface used for system access. The session 490 adds and removes call objects 492_i as dictated by the progression of the call. Each session 490 has a reference number for the session that is based on the originator's board span and channel. However, the session may also

be indexed by an index number of the board, span and channel of any of the parties involved in the session. As shown in Figure 29b, each party object has its own data related to the customer or the interface to which it is related.

The authentication process may be initiated as a result of either a service request by a mobile unit or following the successful page of a mobile unit, but is performed primarily under the control of the VLR. The authentication process may be set up to be performed every time a mobile unit originates a call or when a call terminates at a mobile unit. Authentication may also take place whenever a location is updated for the mobile unit that is in a power on or an idle state. Finally, authentication may occur when a mobile unit registers by turning power on.

When a mobile unit originates a request for service, the mobile unit sends a message to the MSC, including the IMSI, a mobile identification number (MIN), or a temporary mobile subscriber identification (TMSI). The MSC may use the IMSI, the MIN, or the TMSI as the primary identification for the mobile unit. The IMSI is a permanent number that is assigned to every mobile unit. The MIN is a permanent number assigned to a mobile unit in the case where an IMSI is not used. (MIN is used in older AMPS based mobile units). The TMSI is assigned to a mobile unit only after an authentication, and has only local significance. If the TMSI is not recognized from the mobile unit, then a request is made to use the IMSI to continue the authentication. Upon successful authentication, a new TMSI (if used) is assigned to the mobile unit for future system access.

The authentication center is the source of data used in authentication. The authentication center does not store data for the customers. Instead, the authentication performs calculations using random numbers that are used in conjunction with data in the HLR to generate authentication data. When a customer first subscribes for service, the customer is assigned a secret key (K_i for GSM, A-key for CDMA, TDMA). The key and a random number supplied by the authentication are used by the authentication center to generate a result. The data calculations also yield values used for encryption keys. Depending on the protocol (GSM or IS-41 based), the

authentication process can occur at different times during the establishment of communications between the mobile unit and the MSC 210. The similarities between the authentication procedures are found in the fact that they produce results that are used for both access verification and encryption. Although the security calculations the responsibility of the authentication center, the initiation of the actual collection/transmission of data and the comparison to determine the validity of the access is the responsibility of the ARS 434 thread.

When authentication is requested, the MSC sends the random number of the mobile unit. The mobile unit retrieves the K_i from its initialization memory and calculates a signed response (SRES) and an encryption key K_c. The mobile unit then stores the K_c and sends the SRES to the MSC. The ARS 434 identifies that the SRES sent by the mobile unit matches the SRES calculated by the ARS 434. If the values match, the value of K_c stored in the mobile unit is assumed to be correct. This authentication process does not require that the encryption key K_c or the initial key K_i be transmitted over the air, thereby ensuring security for the encryption process.

An example of the GSM authentication process is described with reference to Figure 29c. The authentication process starts with step S10. The process then moves to step S12 where a mobile unit sends a service request message to the aircore platform 200. The message includes the temporary mobile subscriber identification (TMSI). The process them moves to step S14. In step S14, the ARS 434 compares the TMSI sent from the mobile unit to the TMSI recorded in the VLR 422. If the ARS 434 recognizes the TMSI, the process moves to step S20. Otherwise the process moves to step S16.

In step S16, the ARS 434 requests the IMSI for the mobile unit from the VLR 422. The process then proceeds to step S20. In step S20, the aircore platform 200 sends a message to the mobile unit indicating that the mobile unit is recognized. The process then moves to step S24.

In step S24, the mobile unit sends an authentication request message to the aircore platform 200. The process then moves to step S28. In step S28, the aircore

platform 200 sends a random number to the mobile unit and the authentication center platform 200 sends a random number to the mobile unit and the authentication center calculates a signed response (SRES) based on the random number. The process then moves to step S30.

In step S30, the mobile unit, after receiving the random number, retrieves the case K_i from its initialization memory and calculates the SRES and the encryption key K_c. The process then moves to step S34. In step S34, the mobile unit stores the encryption key K_c and sends the SRES to the aircore platform 200. The process then moves to step S38. In step S38, the ARS 434 compares the SRES calculated by the mobile unit with that calculated authentication center 200. If the two SRESs match, the process moves to step S44. Otherwise the process moves to step S40. In step S40, the aircore platform 200 sends a message to the mobile unit indicating that the authentication failed.

In step S44, the ARS 434 completes the authentication process. The process then moves to step S48. In step S48, the ARS 434 determines if the mobile unit needs a TMSI. If the mobile unit needs a TMSI, the process moves to step S50. In step S50, the ARS 434 assigns a TMSI to the mobile unit and stores the value of the TMSI in the VLR 422. The process then moves to step S60. In step S60, the authentication process ends and call processing continues. The message flows associated with a failed authentication are shown in Figure 58.

The above-described authentication process is the GSM authentication procedure, which is one of several authentication procedures available to the MSC. Other authentication processes may vary according to the call processing protocol, for example.

The operation of the aircore platform 200 in a multi-protocol wireless environment is explained below with reference to Figures 30-72.

When the aircore platform 200 and base station controllers are first brought on line, they exchange messages to ensure that all circuits are properly aligned. Figure 30 shows the reset and reset acknowledgment function when the base station controller is

started. In Figure 30 base station controller (BSC) 105 sends a reset message 620 to the device handler DH-7 510 to initiate the message sequence. The DH-7 510 transfers the message to the AMH 431 using DH-7_AMH_TRANSFER 621. The AMH 431 then sends an AMH_REC_RESET 622 to the REC 402 to initiate the reset. The REC 402 returns a reset acknowledge to the BSC 105 using the REC_AMH_RESET_ACK 623, which is sent to the AMH 431. The AMH 431 transfers the reset acknowledgment to the DH-7 510 using AMH_DH-7_TRANSFER 624. The DH-7 510 then sends a RESET_ACK 625 to the BSC 105. The BSC 105 then sends a BLOCKING or CIRCUIT_GROUP_BLOCK 626 to the DH-7 510. The DH-7 510 sends a DH-7_AMH_TRANSFER 627 to the AMH 431, which in turn sends an AHM_REC_ BLOCKING or AMH_REC_CIRCUIT_GROUP_BLOCKING 628 to the REC 402. This process then continues until all the circuits are in the appropriate state on the side of the aircore platform 200.

Figure 31 shows the reset and reset acknowledgment message flows for a base controller failure. The message flows are similar to those shown in Figure 30.

Figure 32 shows the message flows for the start up of the aircore platform 200. Upon startup, the REC 402 sends a REC_AMH_RESET 640 to the AMH 431. The AMH 431 transfers the reset message to the DH-7 510, using an AMH_DH7_ TRANSFER 641, and starts a T16 timer 644 using AMH_TMR_SET_TIMER (RESET) 643. The reset signal (RESET 642) is then sent to the BSC 105. The BSC 105 returns a RESET_ACK 645 to the aircore platform 200 and the AMH 431 releases the T16 timer 644 using AMH_TMR_RLS_TIMER (RESET) 647. The AMH 431 then passes the reset acknowledgment to the REC 402 using AMH_REC_RESET_ACK 648. Finally, the BSC 105 indicates blocking or circuit group blocking by sending an appropriate message to the aircore platform 200. This process continues until all the circuits are in the appropriate state on the side of the aircore platform 200.

Figure 33 shows the message flows for startup of the aircore platform 200 in the event of a circuit failure.

Figure 34 shows the message flows for startup of the aircore platform 200 in the event the T16 timer 644 times out before the BSC 105 returns a reset acknowledgment message to the aircore platform 200.

The aircore platform 200 may interface with other wireless systems. To set up a call, trunks are established between the two systems. Figures 35-40 are flow charts that show the message traffic used to establish and reset the trunks. Figure 35 shows the message flows when a far end system sends a blocking request to the aircore platform 200. A blocking 700 is received from the BSC 105 and transferred to the REC 402. The REC 402 returns a REC_AMH_BLOCKING_ACK 703 to the BSC 105. The state of the trunk circuit established could move to blocked or to blocked pending depending on whether a call is currently on the channel. The REC 402 assures the appropriate state changes occur.

Figure 36 shows the message flows for resetting a trunk circuit when no call is in progress. The BSC 105 sends a RESET_CIRCUIT 710 which is received at the REC 402. The REC 402 returns a REC_AMH_RESET_CIRCUIT_ACK 714 to the BSC 105 and the circuit is reset.

If a call existed on the trunk circuit, the message flows vary from that shown in Figure 36. Figure 37 shows the message flows in this situation. In Figure 37, the BSC 105 sends a RESET_CIRCUIT 720, which is transferred to the REC 402. The REC 402 sends a REC_CPM_CLEAR_CALL 723 to the CPM 414. The CPM 414 sends a CLEAR_CALL 724 to the AMH 431. The AMH 431 then clears the call. In parallel, the REC 402 sends a REC_AMH_RESET_CIRCUIT_ACK 725, which is transferred (726, 727) to the BSC 105.

The trunk circuit may also be reset by action taken by the aircore platform 200. Figure 38 shows the message flows in this situation. The REC 402 initiates a REC_AMH_RESET_CIRCUIT 730, which is transferred (736, 738) to the BSC 105. The AMH 431 sets the T12 timer 734 using an AMH_TMR_SET_TIMER (RESET_CIRCUIT) 733. The BSC 105 returns a reset circuit acknowledgment using RESET_CIRCUIT_ACK 735, which is transferred (736, 738) to the REC 402.

Because the REC 402 received the reset circuit acknowledgment before expiration of the T12 timer 734, the AMH 431 sends (737) a timer release message to the TMR 437 releasing the T12 timer 734.

In some cases, the BSC 105 will not return a reset circuit acknowledgment message before expiration of the T12 timer 734. Message flows in this situation are shown in Figure 39. When the T12 timer 734 times out, AMH 431 (747) sends a time out message to the REC 402. The REC 402 then repeats the reset circuit procedure n number of times, where n is a setable parameter. When the nth attempt to reset the trunk circuit fails, an alarm is raised at the Operations and Maintenance system. The far end state of the circuit remains in an unknown state.

Figure 40 shows the message flows associated with opening a trunk circuit. The message flows are similar to those in Figure 35.

The aircore platform 200 maintains the current location of mobile customers using the VLR 422 and HLR 424. When a mobile customer enters the region serviced by the aircore platform 200, the mobile customer's mobile unit 112 will register with the aircore platform 200. Figures 41 through 47 show the message flows associated with this registration process.

Figure 41 shows the message flows associated with the successful updating by location of a mobile unit 112. The flow assumes the mobile unit's profile has been previously retrieved and is stored in the VLR 422, and therefore no interaction is shown with the HLR 424. The BSC 105 sends (760) a location update request to the aircore platform 200. The request is received at the DH-7 510, which transfers (761) the update request.

At the ARS 434, the update request triggers authentication processing if the mobile unit 112 operates according to IS-41 protocols. The update request is then passed (763, 764) to the VLR 422. The VLR 422 updates the active file for the mobile unit 112 and returns a VLR registration notification response to the BSC 105. When the VLR registration notification response reaches the ARS 434, GSM authentication and ciphering are completed, if the mobile unit 112 operates according

to GSM protocols. The BSC 105 receives a LOCATION_UPDATING_ACCEPT 769 message from the DH-7 510. The DH-7 510 also provides a CLEAR_COMMAND 771 to the BSC 105. At this time, GSM TMSI reallocation occurs. The BSC 105 sends a CLEAR_COMPLETE 772 to the DH-7 510, which in turn sends a DH-7_ AMH_TRANSFER 773 to the AMH 431.

Figure 42 shows the message flows associated with location updating in the event the registration notification request is rejected. Figure 43 shows the message flows if the mobile unit 112 powers down while operating in the vicinity of the aircore platform 200.

Figure 44 shows the message flows associated with a periodic update in which the mobile unit 112 is already registered in the local VLR with the subscriber profile already having been retrieved from the HLR. The BSC 105 sends a LOCATION_ UPDATE_ REQUEST 1400, which is transferred (1401) to the AMH 431. The AMH 431 sends an AMH_ARS_LOCATION_UPDATING_REQUEST 1402 to the ARS 434. At this point, authentication may be performed (1404) for IS-41 protocol equipment. The ARS 1406 then sends an ARS_IMH_AUTHENTICATION_ REQUEST 1406 to the IMH 432. The IMH 432 then sends an IMH_VLR_ REGNOT_REQUEST 1408 to the VLR 422.

The mobile unit 112 was previously registered in the VLR 422. Therefore, the mobile unit's location is simply updated, and a VLR_IMH_REGNOT_RESPONSE 1410 is returned to the IMH 432. The IMH 432 sends an IMH_ARS_ AUTHENTICATION_RESPONSE 1412 to the ARS 434, which in turn sends (1414) and authentication result to the AMH 431. The AMH 431 then sends (1416) a LOCATION_UPDATING_ACCEPT 1418 to the BSC 105. The aircore platform 200 may also perform GSM authentication and ciphering (1413) and TMSI reallocation (1419).

The AMH 431 sends (1421) a CLEAR_COMMAND 1420 to the BSC 105. The BSC 105 returns a CLEAR_COMPLETE 1422 to the DH-7 510, which sends a DH7_AMH_TRANSFER 1423 to the AMH 431.

Figure 45 shows the message flows associated with location updating in which the mobile unit is not currently listed in the local VLR, but is listed in the local HLR. The initial message flows 1430 - 1438 are the same as shown in Figure 44 (1400 - 1408), including authentication (1434) for IS-43 protocol systems. However, the mobile unit 112 is not listed in the VLR 422. The VLR 422 returns a VLR_IMH_ REGNOT_ RESPONSE 1440 that indicates the mobile unit 112 is not registered in the VLR 422. In response, the IMH 432 sends an IMH_HLR_REGNOT_REQUEST 1442 to the HLR 424. The mobile unit 112 is registered in the HLR 424, and the HLR 424 returns an HLR_IMH_REGNOT_ RESPONSE 1444 to the IMH 432. The IMH 432 then sends an IMH_VLR_ REGNOT_RESPONSE 1446 to the VLR 422 to register the mobile unit 112 in the VLR 422. In response, the VLR 422 returns a VLR_IMH_REGNOT_ RESPONSE 1448 to the IMH 432 to indicate that the mobile unit 112 is registered in the VLR 422. The remaining message flows (1450 - 1464) are similar to those (1412 - 1422) shown in Figure 44.

Figure 46 shows the message flows when the IMH 432 determines that the mobile unit 112 is homed to an external HLR. The IMH 432 makes this determination based on an identification of the mobile unit 112 that is provided with the initial location update request messages. In Figure 46, the initial message flows (1480 - 1488) are similar to those shown in Figure 44. The VLR 422 notifies the IMH 432 that the mobile unit 112 is not registered in the VLR 422. Based on the identification of the mobile unit 112, the IMH 432 then determines that the mobile unit 112 is registered in an external HLR. The identification is used to locate the external HLR. The IMH 432 sends a MAP_UPDATE_LOCATION_INVOKE (GSM) or a REGISTRATION_ NOTIFICATION_INVOKE (IS-41) 1492, 1493 to the external HLR. The IMH 432 also sets a REGNOT timer 1496. The external HLR returns (1494) a MAP_UPDATE_LOCATION_RESULT (GSM) or a REGISTRATION_NOTIFICATION_RETURN _RESULTS (IS-41) 1495 to the MSC 210. The IMH 432 releases the REGNOT timer 1496 and sends an IMH_VLR_ REGNOT_RESPONSE 1498 to the VLR 422, causing the mobile unit 112 to be

registered in the VLR 422. The VLR 422 then returns a VLR_IMH_REGNOT_RESPONSE 1499 to the IMH 432. The remaining message flows (1500 - 1509) are similar to those shown in Figure 44.

Figure 47 shows the message flows when the IMH 432 determines that the mobile unit 112 is homed to an external HLR, but the REGNOT timer 1496 times out before the external HLR returns a response. The IMH 432 makes this determination based on an identification of the mobile unit 112 that is provided with the initial location update request messages. In Figure 47, the initial message flows (1510 - 1524) are similar to those shown in Figure 46. When the REGNOT timer 1496 times out, the TMR 437 sends a TMR_IMH_TIMER(REGNOT) 1525 to the IMH 432. The channel is cleared (1526 - 1535) in a manner similar to that in Figure 47.

Figures 48-71 show the message flows associated with call processing. Figure 48 is a flow chart for a mobile originated call. The mobile originated call begins when the BSC 105 receives an indication from the mobile unit 112 that the mobile unit 112 will originate a call. The BSC 105 may receive the number of the called party that was dialed at the mobile unit 112.

The BSC 105 transmits a CM_SERVICE_REQUEST 800 to the aircore platform 200 where the message is received and processed by the DH-7 510. The DH-7 510 establishes the SS-7 link and ensures proper message routing for the inbound message. The DH-7 510 sends a DH-7_AMH_TRANSFER 801 to the appropriate AMH 431 (either the GSM or the IS 634 thread). The AMH 431 sends an AMH_ARS_CM_SERVICE_REQUEST 802 to the ARS 434.

The ARS 434 provides the appropriate calculations and processing to authenticate the given base station interface. The ARS 434 then sends an ARS_IMH_AUTHENTICATION_REQUEST 803 to the appropriate IMH 432. The IMH 432 sends an IMH_VLR_REGNOT_REQUEST 804 to the VLR 422 to notify the VLR 422 of the incoming call. The VLR 422 registers the mobile unit 112 as an active unit and then sends a VLR_IMH_REGNOT_RESPONSE 805 to the appropriate IMH 432. The IMH 432 sends an IMH_ARS_AUTHENTICATION_RESPONSE 806

to the ARS 434. If the mobile unit 112 uses a GSM protocol, GSM authentication and ciphering are completed at this point.

The ARS 434 sends an ARS_AMH_AUTHENTICATION_RESULT 807 to the AMH 431 and the appropriate AMH 431 sends an AMH_DH-7_TRANSFER 808 to the DH-7 510. The DH-7 510 sends a CM_SERVICE_ACCEPT 809 to the BSC 105 indicating to the BSC 105 that the mobile unit 112 is allowed to proceed with the call processing using the aircore platform 200.

During the above-described processing for a GSM protocol mobile unit, the ARS assigns the call a temporary mobile subscriber identity (TMSI). The TMSI is calculated based on an index in the VLR 422, the time of day, and the identity (IMSI) of the mobile unit 112. The TMSI provides additional security so that if the mobile call is tapped, the identity of the calling mobile party cannot be determined.

In Figure 48, the mobile call process then proceeds to the call setup stage and the BSC 105 transmits a SETUP 810 to the DH-7 510. The SETUP 810 includes the call number and an identity of the mobile customer. The DH-7 510 transfers the information to the appropriate AMH 431 by sending a DH-7_AMH_TRANSFER 811. The AMH 431 then notifies the CPM 414 that a mobile originated call has been received by sending a CALL_RECEIVED 812. When the CPM 414 is notified that the mobile call has been received, the CPM 414 allocates a voice channel for a mobile call to carry the voice between the aircore platform 200 and the BSC 105. The mobile call is assigned a session number and each party of the mobile call is assigned an object of the mobile call.

The AMH 431, the DH-7 510 and the BSC 105 communicate through a series of messages 813-821 that the call assignment request has been made and completed. During this processing, a T10 timer 818 is used to time out the call in the event a voice channel cannot be readily assigned. Once the channel assignment is complete and the radio and voice channels are assigned, the AMH 431 sends a ROUTE_CALL 822 to the CPM 414, informing the CPM 414 to proceed with the call because all of the incoming wireless communication requirements have been established. The CPM

414 determines, based on the number that is to be dialed out, what facility the call should go to and in what format. The CPM 414 sends a MAKE_CALL 823 to the appropriate device handler (DHD 501, DHI 503 or DH-7 510) for a land-based or wired call. If the number to be dialed is for a mobile unit, the CPM 414 sends a location request (not shown) through the IMH 432 to the HLR 424 to find out where the called mobile customer is.

As shown in Figure 48, the device handler returns a CALL_ALERTING 824 to the CPM 414 indicating an attempt to connect to the called party. The alerting message is then passed to the BSC 105 using an ALERT_CALL 825, AMH_DH-7_TRANSFER 826 and an ALERTING 827.

After the MAKE_CALL 823 is transmitted, the called party should return a signal to the appropriate device handler, which then sends a CALL_CONNECTED 828 to the CPM 414. The CPM 414 sends a CONNECT_CALL 829 to the AMH 431, which propagates as a CONNECT 831 to the BSC 105. At the same time, the AMH 431 sets a T313 timer 833 using a AMH_TMR_SET_TIMER (CONNECT) 832 to the TMR 437. The TMR 437 then waits for a connection acknowledgment that indicates the called party and the calling party are connected. In particular, the BSC 105 sends a CONNECT_ACK 834 to the DH-7 510, and the connect acknowledgment is propagated (835) to the AMH 431. The AMH 431 then releases the T313 timer 833 by sending an AMH_TMR_RECS_TIMER (CONNECT) 836 to the TMR 437. At this point, the mobile originated call is connected.

Figure 49 shows call processing for normal mobile termination. The aircore platform 200 receives a call at a device handler 501 or 503. The device handler sends a CALL_RECEIVED 840 to the CPM 414. The CPM 414 forwards a CPM_IMH LOCATE_SUBSCRIBER 841 to the IMH 432 initiating a subscriber location action (not shown) in which the HLR 424 (not shown) is queried to determine the location of the called mobile unit 112. The IMH 432 returns an IMN_CPM_SUBSCRIBER_LOCATION 842 to the CPM 414 indicating the location of the mobile 112 unit within the wireless area served by the aircore platform 200. The CPM 414 then initiates a

CPM_PAG_PAGE_MOBILE 843 to the PAG 435 to page the called mobile unit 112. The called mobile unit 112 is then paged (845, 846) and returns a response (850-852). At the same time, the AMH 431 initiates a timer 855 that will timeout the page request if a page response from the mobile unit 112 is not received within a set time period.

As shown in Figure 49, once the page response is received, the ARS 434 initiates an ARS_IMH_ AUTHENTICATION_REQUEST 853 to the IMH 432. The IMH 432 sends an IMH_VLR_REGNOT_REQUEST 854 to the VLR 422 to retrieve the profile information from the VLR 422 for the mobile unit 112. The VLR 422 returns a VLR_IMH_REGNOT_ RESPONSE 857 containing the requested data for the mobile unit 112 in the VLR 422.

During the time period that the mobile unit 112 is being paged and the authentication and registration notification messages are being passed, authentication and ciphering, may occur. In particular, for IS-41 protocol systems, authentication may occur at block 848. For GSM protocol systems, GSM authentication, ciphering and TSMI reallocation may occur at block 859.

As shown in Figure 49, when the AMH 431 receives the authentication result, the AMH 431 initiates an AMH_PAG_PAGE_RESPONSE 861 which is passed (862) to the CPM 414. The CPM 414 then initiates a MAKE_CALL 863. The aircore platform 200 then proceeds to call setup, channel assignment, alerting, call connection and call connection acknowledgment (864-889).

Figure 50 shows a mobile terminated call in which no response is received to the PAGE_MOBILE message, and the page timer times out. In Figure 50, the messages 900-906 are similar to messages 840-846 of Figure 49. An AMH_TMR_SET_TIMER (PAGE_RESPONSE) 907 is sent by the AMH 431 to the TMR 437. When the AMH 431 fails to receive a response to the page request, the timer 908 times out in the TMR 437, and the TMR 437 sends a TMR_AMH_TIMER (PAGE_RESPONSE) 910 to the AMH 431. The AMH 431 then initiates a series of messages 911 to 916 to update the VLR 422. The CPM 414 receives a PAGE_CPM_

PAGE_RESPONSE 918 indicating no response to the mobile page, and as a result the CPM 414 does not issue a MAKE_CALL message.

Figure 51 shows the message flows associated with a PSTN initiated disconnect. The device handler (DHD 501 or DHI 503) receives a disconnect signal from a telephone or other device connected to the PSTN. The device handler sends a DISCONNECT_CALL 930 to the CPM 414, which returns a CLEAR_CALL 932 to the device handler and issues the CLEAR_CALL to the AMH 932. As a result, a DISCONNECT (GSM) or RELEASE (IS-634) 934 is sent to the BSC 105, which returns a RELEASE (GSM) or RELEASE_COMPLETE (IS-634) 938. A T305 or T306 (GSM) or T308 (IS-634) timer 936 is also set in the TMR 437, and if the RELEASE or RELEASE_COMPLETE 938 is not received before expiration of the timer 936, the channel is released.

Once the RELEASE or RELEASE_COMPLETE 938 is received, the AMH 431 sends a CALL_CLEARED 944 to the CPM 414, and a RELEASE_COMPLETE 943 is sent to the BSC 105. The DH-7 510 then sends a CLEAR_COMMAND 946 to the BSC 105, and an internal timer 948 is set in the TMR 437. The BSC 105 returns a CLEAR_COMPLETE 949, and the internal timer 948 is released.

Figure 52 shows a mobile originated disconnect. A DISCONNECT (GSM) or RELEASE (IS-634) 960 is received at the DH-7 510 from the BSC 105. The DH-7 510 transfers the message to the AMH 431, which initiates a DISCONNECT_CALL 962 to the CPM 414. The CPM 414 initiates a CLEAR_CALL 964 to the AMH 431 and the device handler 501 or 503. The AMH 431 transfers (965) the CLEAR_CALL 964 command to the DH-7 510, which initiates a release (GSM) or RELEASE_COMPLETE (IS-634) 966. The device handler 501 or 503 sends a CALL_CLEARED 967 to the CPM 414. The AMH 431 also initiates a T308 timer 964 (GSM) to clear the channel in case a RELEASE_COMPLETE message is not received from the mobile unit 112 within the time period set by the T308 timer 964. The BSC 105 returns a RELEASE_COMPLETE (GSM) 970 to indicate that the mobile unit 112 has completed disconnect, and the AMH 431 releases the T308 timer 964 and sends a

CALL_CLEARED 975 to the CPM 414. The AMH 431 sends an AMH_DH-7_TRANSFER 967 to the DH-7 510, which initiates a CLEAR_COMMAND 977 to the BSC 105. The AMH 431 also sets an internal timer 980 to clear the channel in the event that a CLEAR_COMPLETE message is not received from the BSC 105. The BSC 105 then initiates a CLEAR_COMPLETE 978 and the AMH 431 releases (981) the internal timer 980.

Occasionally, a base station may not return a response to the MSC 210 within the timeout specified. The message flows for this situation is shown in Figure 53. The message flow begins after the service request message flows shown in Figure 48 (messages 800 - 809) are completed. A SETUP 960 is sent from the BSC 105 and in response, the AMH 431 sends a CALL_RECEIVED 991 to the CPM 414 and sets the T10 timer 818. Because the BSC 105 does not return a response to the ASSIGNMENT_ REQUEST 996, the T10 timer 818 times out and the AMH 431 sends a DISCONNECT_CALL 1000 to the CPM 414 to initiate a clear call sequence. The CPM 414 sends a CLEAR_CALL 1001 to the AMH 431, which is passed (1002) to the BSC 105 as a DISCONNECT (GSM) or RELEASE (IS-634) 1003. The AMH 431 also sets (999) a channel release timer 936 in order to release the channel if the BSC 105 does not respond to the DISCONNECT 1003.

The BSC 105 then sends a RELEASE (GSM) or RELEASE_COMPLETE (IS-634) 1004, which is transferred (1005) to the AMH 431. The AMH 431 releases (1006) the timer 936, sends a CALL_CLEARED 1007 to the CPM 414, and sends (1008) a RELEASE_COMPLETE 1009 (GSM) to the BSC 105. The AMH 431 then sends (1010) a CLEAR_COMMAND 1011 to the BSC 105 and sets (1012) an internal timer 1013. The BSC 105 returns a CLEAR_COMPLETE 1014, which is transferred (1015) to the AMH 431, which then releases (1016) the internal timer 1013.

Figure 54 shows the sequence of a time out of the T10 timer 818 for a mobile terminated call. The initial message flows are the same as messages 840 - 860 shown in Figure 49 and are not repeated in Figure 54. The AMH 431 sends a

AMH_PAG_PAGE_ RESPONSE 1020 to the PAG 435, which is passed (1021) to the CPM 414. The CPM 414 sends a MAKE_CALL 1022, which is passed as a SETUP 1025 to the BSC 105. The BSC 105 returns a CALL_CONFIRMED 1027. The T303 timer 869 is set (1026) and released (1028, 1029). The BSC 105 receives an ASSIGNMENT_REQUEST 1031, and the AMH 431 sends an AMH_TMR_SET_TIMER (ASSIGNMENT_REQUEST) 1032 to set the T10 timer 818. However, the BSC 105 does not send a response to the ASSIGNMENT_REQUEST 1031, and the T10 timer 818 times out. As a result, the AMH 414 sends a DISCONNECT_CALL 1036 to initiate tear down of the channel. The CPM 414 then sends a CLEAR_CALL 1037, and the channel teardown proceeds through several message sequences to release the channel and to report that the call is cleared (1038 - 1054) in the same manner as shown in Figure 53. Coincident with the CLEAR_CALL 1037, the CPM 414 may send the calling party an announcement to inform the calling party that the call cannot be completed to the mobile unit 112.

Figure 55 shows the message flows associated with a mobile originated call when the channel assignment fails. Channel assignment failure can occur for a variety of reasons including when the BSC 105 and the MSC 210 do not agree on the state of the channel, for example. The BSC 105 and the MSC 210 will not agree on the state of the channel if the BSC 105 indicates the channel is blocked and the MSC 210 indicates the channel is unblocked, for example. The BSC 105 also may incur a failure in the establishment of the radio portion of the connection.

In Figure 55, a service request is initiated using the same message sequence (800 - 809) as shown in Figure 48. The BSC 105 then sends a SETUP 1060, which is received at the DH-7 510. The message is transferred (1061) to the AMH 431, which sends a CALL_RECEIVED 1062 to the CPM 414. The call proceeds through call setup (1063 - 1065) until an ASSIGNMENT_REQUEST 1066 is sent to the BSC 105. In this case, however, the BSC 105 returns an ASSIGNMENT_FAILURE 1070. As a result, the MSC 210 proceeds with call tear down (1071 - 1090) in the same manner as shown in Figure 53 (1002-1016).

Figure 56 shows the message flow associated with a mobile terminated call when the channel assignment fails. In Figure 56, the initial messages (840 - 860) shown in Figure 49 have already been completed. The AMH 431 then sends an AMH_PAG_PAGE_RESPONSE 1095 to the PAG 435, which passes the message (1096) to the CPM 414. The call setup phase begins with a MAKE_CALL 1097, a SETUP 1101, a CALL_CONFIRMED 1103 and an ASSIGNMENT_REQUEST 1107.

The BSC 105 returns an ASSIGNMENT_FAILURE 1109, indicating, for example, that the BSC 105 and the MSC 210 do not agree as to the state of the channel allocated between the BTS and the MSC 210. The AMH 431 sends a DISCONNECT_CALL 1112 to the CPM 414, which returns a CLEAR_CALL 1115. Call tear down then proceeds in the same manner as shown in Figure 53.

Figure 57 shows the message flows associated with a call disconnect when the CLEAR_COMMAND internal timer times out. For the PSTN initiated disconnect and the mobile originated disconnect, the message flows are the same once the CALL_CLEARED 1135 is sent by the AMH 431 to the CPM 414. The AMH 431 sends (1136) a CLEAR_COMMAND 1139 to the BSC 105 and sets (1137) a CLEAR_COMMAND internal timer 1138. The BSC 105 does not respond with a CLEAR_COMPLETE message, and the internal timer 1138 times out (1140) releasing the channel.

Figure 58 shows the message flows when the MSC 210 rejects a CM service request. The BSC 105 sends a CM_SERVICE_REQUEST 1145 to the MSC 210. The DH-7 510 determines the protocol of the sending mobile unit 112 and spawns an appropriate thread and forwards (1146) the CM_SERVICE_REQUEST 1145 to the AMH 431. The AMH 431 sends an AMH_ARS_CM_SERVICE_REQUEST 1147 to the ARS 434, which forwards an ARS_IMH_AUTHENTICATION_REQUEST 1148 to the IMH 432. The ARS in turn sends a registration notification (IMH_VLR_REGNOT_REQUEST 1149) to the VLR 422. The VLR 422 returns a response (1150) that rejects the service request. This response is passed (1151) to the ARS

434, which sends a CM_SERVICE_REQUEST 1152 to the AMH 431. The AMH 431 transfers (1153) the rejection to the BSC 105 as a CM_SERVICE_REJECT 1154.

Figure 59 shows the message flows associated with a mobile terminated call in which the CPM 414 times out waiting for an alerting message from the AMH 431. The initial message flows are the same as shown in Figure 49 (i.e., 840 - 860). The AMH 431 sends (1155) a page response to the PAG 435, which forwards (1156) the page response to the CPM 414. The CPM 414 sends a MAKE_CALL 1157 to the AMH 431, which transfers (1158) the message as a SETUP 1159 to the BSC 105. The CPM 414 also sets the T310 timer 876, waiting on receipt of an alerting message. The BSC 105 returns a CALL_CONFIRMED 1165, which is passed (1166) to the AMH 431. A channel assignment is then completed (1168 - 1172). However, the BSC 105 does not send an alerting message to the MSC 210, and the T310 timer 876 times out in the CPM 414. As a result, the CPM 414 sends a CLEAR_CALL 1173 to the AMH 431, which is passed (1174) to the BSC 105 as a DISCONNECT (GSM) or a RELEASE (IS-634) 1175. The call tear down then proceeds (1210-1226) in the same manner as shown in Figure 53 (1002 - 1016).

Figure 60 shows the message flows associated with a mobile terminated call in which the call confirmed timer times out in the TMR 437. The initial message flows are the same as those shown in Figure 49 (840 - 860). The AMH 431 sends an AMH_PAG_PAGE_RESPONSE 1200 to the PAG 435, which forwards (1201) it to the CPM 414. The CPM 414 sends a MAKE_CALL 1203 to the AMH 431 and sets the T310 timer 876. The AMH 431 transfers (1204) the MAKE_CALL 1203 to the BSC 105 as a SETUP 1205 and sets (1206) the T303 call confirmed timer 869 in the TMR 437. However, the BSC 105 does not return a call confirmed message to the MSC 210, and the T303 timer 869 times out (1207). The AMH 431 sends a DISCONNECT_CALL 1208 to the CPM 414 and the CPM 414 responds with a CLEAR_CALL 1209. The call tear down then proceeds (1210-1226) in the same manner as shown in Figure 53 (1002 - 1016).

Figure 61 shows the message flows associated with a mobile terminated call in which the call connect timer times in the CPM 414. The initial message flows are the same as those shown in Figure 49 (840 - 860). The AMH 431 sends an AMH_PAG_PAGE_RESPONSE 1230 to the PAG 435 and call set up proceeds through make call, call confirmed and channel assignment (1231 - 1245). The BSC 105 then sends an ALERTING 1246, which is transferred (1247) to the AMH 431. The AMH 431 sets (1248) a T301 call connected timer 883 in the CPM 414. However, the BSC 105 does not return a connect message, and the T301 timer 883 times out. The CPM 414 sends a CLEAR_CALL 1250 to the AMH 431, and call tear down proceeds in the same manner as shown in Figure 53 (1002 - 1016).

Figure 62 shows the message flows associated with a mobile originated call in which the BSC 105 does not send a connect acknowledge message to the MSC 210 and the T313 connect acknowledge timer 833 times out. The initial message flows are the same as shown in Figure 48 (800 - 809). The call proceeds through setup, channel assignment, alerting and call connection (1270 - 1294). The AMH 431 sets (1293) the T313 connect acknowledge timer 833. However, the BSC 105 does not return a connect acknowledgment, and the T313 timer 833 times out (1297). The MSC 210 then proceeds through call tear down.

Figure 63 applies to GSM and IS-634. Figure 63 shows the message flows associated with a call disconnect (mobile or PSTN originated) in which the T308 (GSM) release complete timer 964 times out. Similar message flows would exist for IS-634 protocol equipment. The initial message flows are the same as shown in Figure 51 or Figure 52. The CPM 414 sends a CLEAR_CALL 1300 to the AMH 431, which is transferred (1301, 1302) to the BSC 105. The AMH 431 also sets (1303) a T308 release complete timer 964. As shown in Figure 63, the BSC 105 does not return a release complete message and the T308 timer 964 times out (1304). The AMH 431 then sends (1305) a second RELEASE 1306 to the BSC 105 and sets (1307) a second T308 timer 964'. The BSC 105 returns a RELEASE_COMPLETE 1308, and the AMH 431 releases (1310) the T308 timer 964'. If the T308 timer 964'

were to expire, the AMH 431 could release the transaction and send a call cleared message to the CPM 414. The MSC 210 may then go through a call clear sequence. Returning to Figure 63, the AMH 431 next sends a CALL_CLEARED 1315 to the CPM 414, sends (1316) a CLEAR_COMMAND 1317 to the BSC 105, and sets (1318) a clear command internal timer 1319. The BSC 105 returns a CLEAR_COMPLETE 1320 to the MSC 210. The AMH 431 then releases the internal timer 1319.

Figures 64 - 66 show the message flows associated with processing a dual tone multiple frequency (DTMF) signal. As shown in Figures 64 - 66, the BSC 105 initiates the processing by sending a START_DTMF (1330 in Figure 64) and the CPM 414 returns a CPM_AMH_START_DTMF_ACK (1333 in Figure 64).

Figures 67-71 are flow charts showing message handling associated with call processing with an HLR (internal or external).

Figure 67 shows the message flows when an incoming call is received at the MSC 210, a location request is sent to the HLR 424, and the HLR 424 indicates that the mobile unit 112 is operating locally. The DHI 501 sends a CALL_RECEIVED 1536 to the CPM 414. The CPM 414 sends a CPM_IMH_LOCATE_SUBSCRIBER 1537 to the IMH 432. The IMH 432 then sends an IMH_HLR_LOCATION_REQUEST 1538 to the HLR 424. The HLR 424 returns a response (1539) indicating that the mobile unit 112 is homed on the local system and is operating locally. The IMH 432 then provides an IMH_CPM_SUBSCRIBER_LOCATION 1540 to the CPM 414 indicating that the mobile unit 112 is operating locally. The remaining message flows 1541 - 1595 are similar to those shown in Figure 49.

Figure 68 shows the message flows associated with an incoming call to a mobile unit 112 that is operating locally but is homed on an external HLR. The DHI 503 sends a CALL_RECEIVED 1600 to the CPM 414, which sends a CPM_IMH_LOCATE_SUBSCRIBER 1602 to the IMH 432. Because the mobile unit 112 is not homed locally, the IMH 432 sends a location request 1600/1608 to the external HLR and sets (1604) a LOCREQ timer 1605. The IMH 432 then receives a return

1610/1612 from the external HLR and releases (1614) the LOCREQ timer 1605. Then the IMH 432 sends an IMH_CPM_SUBSCRIBER_LOCATION 1616 to the CPM 414 indicating the location of the mobile unit's 112 HLR. The remaining message flows 1620 - 1699 are similar to those in Figure 49.

Figure 69 shows the message flows associated with call processing for a mobile termination in which the mobile unit 112 is homed on the HLR 424 but is operating externally to the wireless network controlled by the aircore platform 200. In this case, the mobile unit 112 will be registered on an external VLR. The CPM 414 receives a CALL_RECEIVED 1700 and sends a location request 1702 to the IMH 432. The IMH 432 sends a location request 1704 to the HLR 424. Because the mobile unit 112 is registered on another wireless network, the HLR 424 sends a route request 1706 to the IMH 432, which sends an invoke 1710 to the external VLR and sets a ROUTEREQ timer 1709. The external VLR returns the results 1712 to the IMH 432, and the IMH 432 releases the ROUTEREQ timer 1709. The IMH 432 also sends an IMH_HLR_ROUTE_REQUEST_RESPONSE 1716 to the HLR 424 and the HLR 424 returns a location response 1718. The IMH 432 then sends (1720) the location of the mobile unit 112 to the CPM 414, which issues a MAKE_CALL 1722 to the roaming number provided by the external wireless network serving the mobile unit 112. The process then proceeds through call alerting and call connection.

Figure 70 shows the message flows for call processing for a mobile terminated call when the mobile unit 112 is homed on an external HLR and is operating externally to the wireless network controlled by the aircore platform 200. The CPM 414 receives a CALL_REQUESTED 1730 from the DHD 501. The CPM 414 then sends a CPM_IMH_LOCATE_SUBSCRIBER 1732 to the IMH 432. The IMH 432 sets a timer 1734 and sends an invoke message 1736 to the DH-7 510. The DH-7 510 sends 1736 the invoke message to the external HLR and receives (1738) a response. The DH-7 510 then sends a results message 1739 to the IMH 432. The remaining message flows are similar to those shown in Figure 69.

Figure 71 shows the message flows associated with call processing for a mobile unit 112 homed on an external HLR but operating within the wireless network controlled by the aircore platform 200. In this scenario, the mobile unit 112 receives a call that goes initially to the MSC of the external wireless network. The call is then routed to the wireless network controlled by the aircore platform 200. The MSC 210 receives an invoke message 1751 from the external HLR. The IMH 432 then sends a route request 1752 to the VLR 422. Because the mobile unit 112 is roaming, it will be registered on the VLR 422. The VLR 422 returns a route request response 1753 to the IMH 432, which sends a roaming number 1754 to the external HLR indicating the location of the HLR 424. The remaining message flows are similar to those in Figure 49 with the exception that the IMH 432 does not have to locate the mobile unit.

Figure 72 shows the message flows associated with hand off pre-processing for an ISDN PRI+ protocol. The BSC 105 sends a HANDOFF_REQUEST 1850 to the DHI 503, which sends a HANDOFF_REQUEST 1852 to the HOP 416. The HOP 416 returns a MEASUREMENT_REQUEST 1854 to the DHI 503, which sends a HANDOFF_MEASUREMENT_REQUEST 1856 to the BSC 105. The HOP 416 also sends measurement requests (1854'/1856') to all base stations capable of handling the message traffic from the mobile unit for which the hand off is requested. The BSC 105 returns a HANDOFF_MEASUREMENT_RESPONSE 1858 to the MSC 210, and a MEASUREMENT_RESPONSE 1860 is sent to the HOP 416. Other base stations likewise return measurement responses (1858', 1860') to the MSC 210. The HOP 416 then proceeds with the handoff process. Figure 72 shows the initial message responses for the ISDN PRI+ protocol. Other protocols use similar initial measurement flows to establish a target base station for hand off.

Wireless customers can pay for their services in a variety of ways including an annual subscription and on a monthly basis, for example. In both these cases, the customer pays for the call actually made (air time) plus a periodic base fee. Customers can also pay for wireless services in advance through a prepaid system. Figure 73 is a logical diagram of an aircore prepaid rating system 2100. The aircore

prepaid rating system 2100 includes a data management module 2101, a rating administration module 2102, a distributor data module 2103, and distributor rate plans 2110 through 2119. Thus, a distributor can have up to ten different rate plans. Each customer can select one of the ten different rate plans for each distributor in the aircore prepaid rating system 2100.

The distributor can be viewed much like a class of service is viewed in routing. The distributor is a classification of rating service that is assigned to certain groups of subscribers in the aircore system. A distributor could be a point of sale, a corporate customer, or an operator classification for a group of customers. Within each distributor, there can be up to ten different rate plans configured. A rate plan establishes the air time rates for the plan. The combination of distributor and rate plan provide a comprehensive rating schedule for a variety of combinations within the system.

Within each customer profile 460 (see Figure 20) in the aircore HLR 424, the parameter for prepaid service is configured as prepaid or not. The prepaid configuration of the customer is controlled via a prepaid check box and associated prepaid window and a graphical user interface (see Figure 89). The window is used to define the distributor and rate plan that the customer uses for the prepaid service. Also, the credited amount for the account is input with the prepaid data. This field tracks the amount of service that a customer is allowed on the system. The amount is updated in real-time to track the usage of the system by the customer.

A third part of the prepaid system is bill generation that is integrated as part of a call record management subsystem. The set of functions available allows the operator the ability to create a range of reports based on operator defined billing cycles.

In operation, when a customer who has elected a prepaid plan uses the aircore prepaid rating system 2100, the customer profile 460 is pulled from the HLR 424 to determine the applicable distributor rate plan. The information from the customer profile 460 is passed to the CPM 414. The CPM 414 determines if the customer has

an account balance sufficient to pay for the call. The CPM 414 also determines the least cost route for the call, including defining the land charge and the air time charge associated with the destination and time of day of the call to come up with the per minute charge. This value is then used to set a timer that will indicate when the customer's account reaches a balance that corresponds to two minutes left on a call.

Once the prepaid call has begun, the timer begins a time out process and when the two minute position is reached, a tone warning is provided to the customer indicating that the customer is running out of money. No further warnings are provided, and once the next two minutes have expired, the TMR 437 sends a message to the CPM 414 indicating that the time has expired. The CPM 414 then initiates a call cutoff, terminating the prepaid call. In this way, the customer cannot overrun the prepaid account balance

At the completion of the call, the billing system 260 calculates how much the call actually cost for the customer and updates the amount in the HLR 424. A call detail record (CDR) is prepared that provides the detailed information regarding the call so that the billing system 260 can determine the remaining account balance. The bill generated by the billing system 260 is then used to update the customer profile 460.

In the wireless environment shown in Figure 1a-1d, there may be a need to locate customers who place distress, or emergency (911), calls. These 911 calls are used to gain rapid access to local authorities and emergency service centers. if a customer places a 911 call from a wired device, locating that customer is easy using call tracing procedures. Customers using wireless devices are more difficult to locate.

The air core platform 200 solves the problem of wireless customer location by creating an identification number based on the current position of the customer in the wireless environment. The aircore platform 200 uses the identification number as the dialed number to route the call to an emergency service center. The identification number includes the position data available from the BSS where the call origination is received. The location information received from the BSS is coded in hexadecimal.

The aircore platform 200 converts the hexadecimal number to binary coded decimal (BCD) and uses this number as an indication of the customer's location.

Following is an example of the data conversion used by the aircore platform 200 to convert the location data received from the BSS 110 to a dialed number for emergency callers. The data received could be as shown in the following table in which the BSS 110 receives the location of a customer with cell ID granularity. The MSC 210 converts the data as shown in the table.

FIELD	RESULTING NUMBER OF DIGITS
Mobile Country Code	Up to 3
Mobile Network Code	Up to 3
Location Area ID	Up to 3
Cell ID	Up to 3

The numbers produced from the conversion yields a unique 12 digit number identifying that cell in the system.

The aircore platform 200 may incorporate the concept of customer groups to define the routing translations (classes of service) for the wireless network. A customer group is a table of number ranges that is used to determine if a call is allowable. The aircore platform 200 searches the list of entries in the table. If a match is found, the call is allowed to proceed. If a match is not found, the call is not allowed to proceed in the wireless network.

The aircore platform 200 allows for the definition of up to 256 different customer groups. Each customer in the system, and each trunk, is associated with a customer group when a customer group is initially configured. The customer group that is used for a particular call is determined based on: 1) the customer placing the call; and 2) the trunk that received the call.

For emergency calls, a specific customer group is used to provide the routing translations. For emergency calling, the aircore platform 200 uses emergency translations.

Figure 74 is a flow diagram illustrating emergency call processing using the aircore platform 200. The processing starts as step S100. In step S110, the call is received at the aircore platform 200. The process then moves to step S120. In step S120, the aircore platform 200 determines if the call is an emergency call. If the call is not an emergency call, the process proceeds to step S130 and the call is handled as a normal call. In step S120, if the call is an emergency call, the process moves to step S140. In step S140, the aircore platform 200 converts the location of the mobile unit to a dial-up number. The process then moves to step S150.

In step S150, the aircore platform 200 checks the portion of the customer group associated with emergency calls. The process then moves to step S160. In step S160, the aircore platform 200 determines if the dial-up number from step S140 is in the customer group. If the dial-up number is not in the customer group, the process proceeds to step S170, and the call is routed to a default emergency center. If the dial-up number is the customer group, the process moves to step S180. In step S180, the aircore platform 200 changes the dial-up number to an emergency center number. The process then moves to step S190. In step S190, the call is routed to the emergency center. The process then moves to step S200 and ends.

The aircore platform 200 can also support other communication features. For example, the aircore platform 200 may be used with a long-distance resale system.

The aircore platform 200 can also be used to provide microcellular wireless networks in combination with land-line local networks or private branch exchanges (PBX). There are several standards including computer supported telecommunications applications (CTSA), windows telephony application programming interface (TAPI), and telephony services application programming interface (TSAPI), for example, that allow a PBX to incorporate equipment and features from outside vendors. These protocols also allow for call control and routing

decisions to be made by a system that is external to the PBX. The external system can be used to allow for connectivity, feature processing, and seamless number management that allows customers to use both the PBX infrastructure and a separate wireless system using one telephone number and one customer feature profile.

The aircore platform 200 provides an external control function to integrate a wireless system, or microcell, and a PBX using the technique of third party call control. Figure 75 is a diagram illustrating first party call control. In Figure 75, an application 2010 controls a call from a PBX 2011 to a telephone 2014. The control of the call is related to each of the signals and messages passed between the telephone 2014 and the PBX 2011. First party call control is often used as a call control feature in private branch exchanges.

Figure 76 illustrates third party call control. In Figure 76, a call control application 2015 provides direct control over termination of a call to the resource such as the telephone 2014. Calls into a PBX 2016 are routed under the control of the call control application 2015. The aircore platform 200 can incorporate the concept of third party call control to add on to the functionality of a PBX. In particular, the aircore platform 200 may be used with a PBX to add in-building wireless communication capabilities to an existing wired private branch exchange.

A standard PBX interface control element (SPICE) may be added to the aircore platform 200 to provide an interface to a PBX. The SPICE includes software that can operate with the control protocols of different PBXs. The SPICE interfaces internally with the HLR 424 and the SCR 314 (see Figure 10). A system operator may interface with the SPICE using a graphical user interface (GUI).

The SPICE provides third party call control messaging needed to provide the notice of an incoming call, decide how to handle the incoming call and send the appropriate commands to route the incoming call to the correct destination. The SPICE may be co-located with the HLR 424, and requires the basic retrieval capabilities of the HLR 424. The customer profile information in the HLR 424 allows the SPICE to determine how to handle a call. For example, the customer profile may

indicate the operational modes for the customer's wired and wireless telephone handsets.

Customers whose PBX incorporates wireless features, including the SPICE, noted above, may designate one or more operational modes for their telephone handsets. Customers may elect to have incoming call terminate at their desktop telephone first. If the desktop telephone is not available, the call may be routed, via a MSRN, to the customer's mobile unit. Second, the call may be first routed to the mobile unit. If the mobile unit is not available, the call may be routed to the desktop telephone. Third, the call may be routed to the customer's mobile unit only. Fourth, the call may be routed to the customer's desktop telephone only. Fifth, the call may be routed to the mobile unit only when operating in the mobile unit's 112 home area.

One advantage of this arrangement is that the HLR 424 may house the full suite of call forwarding features, voice mail and announcements. The customer's profile determines how the call is handled.

If the customer profile indicates that incoming calls are first routed to a mobile unit, the HLR 424 will locate the customer in the telecommunications network and then have an MSRN allocated to deliver the call to the switch where the customer's mobile unit is residing.

If the customer profile lists the desktop telephone as the first call delivery option, the SPICE determines that the call should be terminated to the desktop telephone. If the customer answers the desktop telephone, SPICE's involvement in the call ends. However, if the customer does not answer at the desktop telephone, SPICE processing can determine the appropriate handling for the call. The call could be routed to the mobile unit, voice mail, or an announcement, for example.

Figures 77 - 79 illustrate call routing for various call entry points. In Figure 77, a PBX 2020 receives an incoming call from a PSTN (not shown). The PBX 2020 uses third party call control over a CSTA interface (not shown) to notify (2022) a HLR 2030 that a customer has received an incoming call 2021. The HLR 2030 determines that the customer is currently roaming on another wireless telephone

system, and that the call needs to be delivered to the customer. Using standard mobile application messaging, the appropriate number for the delivery is allocated and sent (2023) to the PBX 2020. Via the CSTA interface, the PBX 2020 is commanded to send the call over the PSTN with the delivery number as the destination. The call arrives at a local MSC 2025 and is delivered (2037, 2038) via a wireless network 2035 to a mobile unit 2036.

Figure 78 shows a scenario for call delivery to the mobile unit 2036 when the local MSC 2025 is the point of entry for the call from the PSTN (not shown). An incoming call 2040 is received from the PSTN at the local MSC 2025. The MSC 2025 communicates (2041) with the HLR 2030 for call delivery information. The HLR 2030 determines that the customer is roaming on another wireless network 2035 and that the call should be delivered to the wireless network 2035. The appropriate number for delivery is allocated and sent (2039) to the MSC 2025. The MSC 2025 then delivers (2042, 2043) the call to the mobile unit 2036.

Figure 79 shows a scenario for call termination to a desktop telephone. In Figure 79, the local MSC 2025 receives an incoming call 2045 from the PSTN (not shown). The MSC 2025 communicates with the HLR 2030 for call delivery information. The HLR 2030 determines that the customer is not registered in the wireless network 2035 and determines that the call should be terminated to the PBX 2020. The HLR 2030 allocates (2047) a delivery number for the PBX 2020. Using standard procedures, the HLR 2030 sends the delivery number to the MSC 2025. The MSC 2025 then delivers (2048) the call 2045 to the PBX 2020. Using third party call control, the HLR 424 associates the call 2045 with a customer and the call 2045 is terminated to the desktop telephone 2014.

Figure 80 shows an aircore platform 2200 that is used to provide an in-building wireless and wired telephone system with third party call control. A building 2210 includes a PBX 2211. The PBX 2211 connects to wired telephones 2212. The building 2210 also includes a microcellular wireless network 2201 serving mobile units 2213. The PBX 2211 connects to the aircore platform 2200 via wired a

connection and a suitable interface such as a RS-232 interface. The aircore platform 2200 includes a base station controller 2206 and a suitable interface to provide wireless communication to the microcellular network 2201. The BSC 2206 may be incorporated as a component on a card in the aircore platform 2200. A separate database 2205, containing information related to customers of the building 2210 may be provided with the aircore platform 2200. Alternately, the data may be included in a home location register in the aircore platform 2200. Finally, macro cellular systems, such as the extended wireless network 2220 with cells 2221 and 2222 may exist external to the microcell 2201.

In operation a customer using both a wired telephone 2212 and a mobile unit 2213 may specify, by entry in the database 2205, for example, which of the wired telephone 2211 and mobile unit 2213 should receive a call. Thus, when a call comes in to a particular customer, the aircore platform 2200 will determine which of the wired telephone 2212 and the mobile unit 2213 to connect to first. The aircore platform 2200 can be further instructed that when the mobile unit 2213 is active, or in a power-on state, all calls should first be routed to the mobile unit 2213. If the mobile unit 2213 does not respond after a certain number of rings, the incoming call can then be routed to the wired telephone 2212. The microcellular network 2201 may also be used for visitors to the building 2210. In this case, a visitor having a mobile unit may have that mobile unit initiate a registration notification when the mobile unit enters the microcellular network 2201. Then, any incoming calls to the visitor's mobile unit will be routed through the aircore platform 2200 to the microcellular network 2201.

When a customer of the building 2210 transits from the microcellular network 2201 to the external wireless network 2220, a location update is performed that deletes the customer's location in a VLR of the microcellular network 2201, and initiates a registration notification with the mobile switching center of the external wireless network 2220. In this way, the exact location of the mobile unit 2213 may be maintained so that calls to a particular customer may be routed in accordance with the customer's routing plan contained in a VLR/HLR or the database 2205.

In the arrangement described above, a particular mobile unit 2213 and wired telephone 2212 may share a common telephone number. In an alternate arrangement, the wired telephone 2212 and mobile unit 2213 may have different telephone numbers.

A microcellular network, such as the microcellular network 2201, may also be adapted for use in large buildings, such as indoor stadiums and convention centers. A mobile switching center such as the aircore platform 2200 may incorporate multi-protocol processing and base stations so that visitors to the convention center may use mobile units inside the convention center regardless of the protocol established for the mobile unit. The aircore platform 2200 may be configured to charge different rates for different visitors to the convention center. People who work in the convention center may be charged yet another rate for using mobile units in the convention center.

The aircore platform 200 may incorporate fault resilient features, which may be particularly desirable for distributed wireless systems. The fault resilient hardware architecture of the aircore platform 200 may be logically split into three layers as shown in Figure 81. A hardware architecture 2300 includes a computing element layer 2310. The computing element layer 2310 includes computing elements 2311 and 2312. The computing elements 2311 and 2312 are connected by an appropriate communications medium such as an ethernet 2313. The ethernet 2313 may have a capacity of 100 Mb or more, for example.

An input/output (I/O) processor layer 2320 includes I/O processors 2321 and 2322. The I/O processors 2321 and 2322 are connected by an appropriate communications medium such as a 100 Mb ethernet 2323. The I/O processors 2321 and 2322 are both connected to each of the computing elements 2311 and 2322 by an appropriate communications medium such as a 40 Mb fiber optic cable 2314.

A telephony interface processor (TIP) layer 2340 includes a plurality of telephony interface processors (TIPs) 2341_1 - 2341_n. The TIPs 2341_1 - 2341_n are connected by a dual rail ethernet 2343. The ethernet 2343 is also used to connect the TIPs 2341_1 - 2341_n with the I/O processors 2321 and 2322.

The three layers described above comprise the three main processing areas of the aircore platform 200. Communications between the three layers provides for a variety of physical layouts and geographical configurations. For example, the fiber optic connection between the computing element layer 2310 and the I/O processor layer 2320 can be geographically separated by 1.5 kilometers or more. The TIPs 2341_1 - 2341_n can be spread geographically and remotely controlled via a centralized computing element layer and I/O processor layer set. Thus, the aircore platform architecture 2300 can be adapted to provide a large distributed wireless network with centralized control or the layers can be co-located.

Figure 82 shows the logical construction of the computing element 2311 in more detail. The computing element 2312 is identical to the computing element 2311 and therefore, only the computing element 2311 will be described. The computing element 2311 includes a central processor 2315, a memory 2316 and a PCI-based connector 2317 that couples the computing element 2311 to the I/O processors 2321 and 2322. Also shown is a memory 2318 that stores the software applications that operate in the computing element 2311. The software applications are described with reference to Figure 10. The memory 2316 may be a random access memory (RAM), for example. The memory 2318 may be a read only memory (ROM), for example.

Figure 83 shows the logical construction of the I/O processor 2321 in more detail. The I/O processor 2322 is identical to the I/O processor 2322 and therefore only the I/O processor 2321 will be described. A PCI interface 2332 connects the I/O processor 2321 to the ethernet 2314. A memory module 2326 includes a hard disk 2327, an interface slot 2328 for a CD-ROM, and an interface 2329 for a floppy disk. A memory 2325 includes the programming to operate the I/O processor 2325. A central processor 2324 controls operation of the I/O processor 2325. An ethernet interface 2330 provides connections to the ethernet 2323 and to the dual rail ethernet 2343. A memory 2333 stores application programs executed by the I/O processor 2321. Finally, SS-7 interface modules 2334 and 2335 provide connections to systems external to the aircore platform 200.

Figure 84 shows the logical construction of the TIP 2341_1. The other TIPs are the same as the TIP 2341_1. A central processor 2344 controls operation of the TIP 2341_1. A memory 2345 includes the operating programs for the TIP 2341_1. A memory 2348 includes the application programs under control of the TIP 2341_1. The application programs are described with reference to Figure 10. An interface 2347 connects the TIP 2341_1 to the dual rail ethernet 2343. A memory module 2346 includes a hard drive 2349 and a floppy disk interface 2350. An external interface module 2349 connects the TIP 2341_1 to systems external to the aircore platform 200.

Figure 85 shows another hardware embodiment of the aircore platform 2400. In this embodiment, the aircore platform 2400 includes a 19-inch rack-mountable chassis 2410. The aircore platform 2400 includes dual loadsharing power supplies 2420 and optional power supplies 2422. The chassis also includes dual mirrored SCSI disk drives 2430 and optional drive bays 2432. An I/O processor board 2440 connects to telephony boards slots 1-14 for telephony boards 2470-2485. Finally, the aircore platform 2400 includes a removable fan tray 2490.

Figure 86 shows the I/O processor in more detail. The I/O processor board 2440 includes a processor 2441 that provides bus control for the telephony boards 2470-2485. The processor 2441 can be an advanced processor such as an Intel Pentium™ family processor or other processor. The I/O board 2440 also includes a scalable random access memory 2442. The I/O processor board 2440 provides on-board PCI video 2443, IDE 2444 and SCSI drive controllers 2445, and multiple serial I/O ports 2446. Also included are Ethernet connections 2447, floppy disk drives 2448, and PCMCIA slots 2449. The I/O processor board 2440 provides front and rear access to the I/O devices. The SCSI drives 2445 may be dual mirrored 1.5 Gb hard drives. The SCSI drives 2445 may be configured in a RAID-1 format. The SCSI drives 2445 are hot swapable and can be resynchronized in case of failure.

The aircore platform 2400 may provide for local network connectivity and dial-out access using a standard 10base-T or 100base-T Ethernet connection for LAN connecting options and a 56k dial-up modem for remote access dial-in capability.

Other advanced telecommunications connection devices may also be used with the aircore platform 2400. Standard telephony boards may be used with the aircore platform 2400 for T-1/E-1 and ATM communications. For example, the telephony boards 2470-2485 include TH-B1240 OCTAL T-1/E-1 interface boards for common channel signaling based T-1s. TH-BD96 quad T-1 interfaces are provided for channel associated signaling using T-1s. TH-BD120 quad E-1 interface devises are used for channel associated signaling using E-1s. TH-BV30 voice I/O provides 30 ports of I/O and signal processing. TH-BC64 provides conferencing capabilities. A TH-BSS7 board provides both DS0 and V.35 connections. Each of the telephony boards 2470-2485 provides 4-6 trunk links. Also connected to the aircore platform 2400 are operator interface devices including a monitor 2491, a keyboard 2492, and a mouse 2493.

The switching architecture of the aircore platform 2300 or 2400 may be the H.110/H.100 based standard, for example. The H.110 and the H.100 switching matrix is a standard Application Specific Integrated Circuit (ASIC) that resides on each board in the system. This means that rather than shipping all interface channels to a single point in the system to make and break the connections for switching, each board controls its own switching. The H.110 switching matrix uses a J4 connector or connects to the other components of the aircore platform 2400 using a J4 connector on a back plane of the chassis 2410. There may be a total of 32 streams running at speeds of 8MH_z Each stream provides 128 channels of 64 kbps. Total bus capacity ranges from 512 to 4096 channels.

The H.100 switching matrix uses a ribbon cable to connect to boards together to provide the actual streams of digitized channels. There are a total of 32 streams running at speeds of 2MH_z to 8MH_z. Each stream provides from 32 to 129 channels of 64 kbps. The total bus capacity ranges from 512 to 4096 channels.

Other switching matrices may also be used with the aircore platform 2400.

The capacity of the aircore platform 2400 may be extended. Multi-chassis configurations can be provided to claim the switch matrices together. This may be

accomplished using several standard multi-chassis interconnection interfaces or by connecting the chassis via E-1 or T-1 connections. The addition of ATM allows for a standard extension mechanism to the switch matrix between chassis.

Other hardware configurations besides the two embodiments described above are available with the aircore platform 200.

The aircore platform 200 incorporates graphical user interfaces (GUIs) to aid operator manipulation of system data. Figures 87-119 show the hierarchy of windows used with the GUIs and also show examples of GUI screens used with the aircore platform 200.

Figure 87 shows the hierarchy of windows used with the aircore HLR 424. A hierarchy 3000 includes a home location register icon screen 3001 which is initially displayed. Upon entry of a password in a password screen 3002, a home location register access screen 3003 is displayed. Using the home location register access screen 3003, an operator can choose one of the screens 3004-3009 for GSM, CDMA, TDMA, AMPS, multi-mode protocols, or for prepaid services. Finally, corresponding to each of the wireless protocols is a separate prepaid screen 3010-3014.

GSM subscriber profiles are configured as per the GSM feature set. CDMA subscriber profiles are configured as per the CDMA (IS-664) feature set. Multi-mode subscriber profiles may be configured for multiple air interfaces. Multi-mode subscribers use the common feature set between the GSM, CDMA, TDMA and AMPS protocols. All of the above subscriber profiles can incorporate prepaid feature functionality.

Prepaid subscriber profiles are configured as strictly prepaid in the aircore system. Prepaid subscribers may use wireless or wireless prepaid features.

Figure 88 shows the GSM subscriber window 3004 in more detail. A number of subscribers block 3021 lists the current number of subscribers in the HLR 424 as well as the capacity of the HLR 424. The subscriber list 3022 individually lists the subscribers to the aircore systems. A previous button 3025 and a next button 3026 loads the previous or next group of subscribers into the subscriber list scroll box 3022.

A properties button 3023 allows modification of data for the selected subscriber. A search button 3024 allows for search of the HLR 424 when a subscriber MSISDN number is input at the search line. An add button 3027 and a delete button 3028 allow the addition or deletion of a subscriber profiled in the HLR 424. A report button 3029 allows an operator to view a change report file created for HLR 424 modifications.

Figure 89 is an example of an individual subscriber profile for a GSM subscriber. The subscriber profile 3030 includes a customer and mobile unit identification block 3031, call offering block 3032, call restriction block 3033, and call restrictions block 3034. Also included is a call features block 3035, and line identification block 3036.

Subscriber profiles for other wireless protocols are similar to that described above for a GSM subscriber.

Figure 90 shows a routing administration windows hierarchy 3110 associated with establishing routing translations in the aircore systems. The initial screen is a database management icon screen 3101. Next, a routing administration tab 3102 is display. Linked to the routing administration tab 3102 is a customer group properties screen 3103. Also linked to the routing administration tab 3102 is a standard routing screen 3104, a feature codes screen 3105, an emergency call routing screens 3106 and a tones and announcement screen 3107. The data displayed in the screens 3104-3107 may be modified by displaying an add/modified/delete screen 3108.

Figure 91 shows the routing administration tab 3102. A customer group scroll box 3111 shows the customer groups that are currently active in the aircore system. The customer group is a required piece of data that is assigned to both customers and trunk groups. The number assigned is used as an index into the appropriate routing table for processing an incoming call. The routing translations determine the allowable calls, the type of call, and the appropriate system routing for the call. Each customer group can accommodate hundreds of individual from-to routing translation entries. The translations can provide support for any dialing plan between 1 and 32 digits. Dialing plans of varying lengths maybe configured within the same customer

group. Each line of translations within each customer group provides a primary and alternate route based on the trunk group. In addition, each route is provided its own digit manipulation parameters (strip and prefix digits). The aircore system can accommodate up to 100 customer groups.

Figure 92 shows a customer group modification window 3120. The customer group modification window 3120 defines the overall properties associated with a particular customer group. Check boxes 3121 allow for the configuration of three alternate types of translations.

Figure 93 shows the standard routing translation window 3104. A scroll box 3131 is used to display portions of the information. The information displayed in the scroll box 3131 includes "from" data, which is the number the range starts from; "to" data, which is the number the range ends at; min, which is the minimum length of the digit string; max, which is the maximum length of the digit string; and type, which is the type of call the number range indicates. Also shown is the route number of the trunk and the numeric trunk group number.

Figure 94 shows the standard routing translations modifications window 3108. The standard routing translations modifications window 3108 provides the operator access to modify the selected number range. The window is used for adding or modifying ranges in the standard routing translations window 3104.

Figure 95 shows the feature code routing translation window 3105. The feature code routing translation window 3105 includes a scroll box 3151 that displays a portion of the information selected by the operator. The feature code routing translation window 3105 contains the information related to routing feature manipulation calls for the aircore system. The parameters supplied in the feature code routing translation window 3105 are used to determined the type of feature manipulation and the appropriate system action.

Figure 96 shows the emergency call routing translations window 3106. A scroll box 3161 displays currently selected information. The information includes "from" data which is the number the digit range starts from. The "from" data can be